United States
Environmental Protection
Agency

Office of Solid Waste and
Emergency Response
(5201G)

March 2012

Superfund

Air Monitoring for Emergency Response

Student Manual

EPA-540-B-00-001
OSWER 9285.9-36

FOREWORD

This manual is for reference use of students enrolled in scheduled training courses of the U.S. Environmental Protection Agency (EPA). While it will be useful to anyone who needs information on the subjects covered, it will have its greatest value as an adjunct to classroom presentations involving discussions among the students and instructional staff.

This manual has been developed to provide the best available current information; however, individual instructors may provide additional material to cover special aspects of their presentations.

Because of the limited availability of the manual, it should not be cited in bibliographies or other publications.

References to products and manufacturers are for illustration only; they do not imply endorsement by EPA.

Constructive suggestions for improvement of the content and format of the Air Monitoring for Emergency Response manual are welcome.

Student Manual

TABLE OF CONTENTS

AIR MONITORING FOR EMERGENCY RESPONSE

presented by
Tetra Tech NUS, Inc.

for the
U.S. Environmental Protection Agency's
Environmental Response Team
Contract Number EP-W-08-054

ENVIRONMENTAL RESPONSE TRAINING PROGRAM (ERTP)

U.S. EPA	United States Environmental Protection Agency
OSWER	Office of Solid Waste and Emergency Response (Superfund)
OSRTI	Office of Superfund Remediation and Technology Innovation
ERT	Environmental Response Team

ERTP TRAINING COURSES

- Are offered tuition-free for environmental and response personnel from federal, state, and local agencies
- Vary in length from one to five days
- Are conducted at locations throughout the United States

ERTP TRAINING COURSES

Course Descriptions, Class Schedules, and Registration Information are available at:

- www.trainex.org
- www.ertpvu.org

COURSE OBJECTIVES

- Properly use the following types of air monitoring equipment:
  - Combustible gas indicators
  - Oxygen monitors
  - Detector tubes
  - Toxic gas monitors
  - Photoionization detectors
  - Flame ionization detectors

COURSE OBJECTIVES

- Identify the operational parameters, limitations, and data-interpretation requirements for these air monitoring instruments plus chemical warfare agent detectors and field analytical technologies
- Identify the factors considered in the development of air monitoring plans
- Discuss the use of air monitoring data for the establishment of personnel and operations health and safety requirements
- Discuss the uses, limitations, and data needs for air dispersion modeling

COURSE MATERIALS

- Student Registration Card
- Student Evaluation Form
- Course Agenda
- Student Manual (disk)
- Workbook
- Student Handouts

COURSE MATERIALS

- Student Registration Card
- Student Evaluation Form
- Course Agenda
- Student Manual
- Facility Information
- Student Handouts

FACILITY INFORMATION

- Parking
- Classroom
- Restrooms
- Water fountains, snacks, refreshments
- Lunch
- Telephones
- Emergency telephone numbers
- Alarms and emergency exits

Please...

In consideration of your fellow students and the instructors, please silence all cell phones and pagers.

COURSE CERTIFICATE

- Attendance is mandatory
- 1.5 CEUs awarded

CHEMICALS USED IN THIS COURSE

- Acetone
- Air, compressed gas
- Ammonia cleaner
- Antifreeze
- Butane
- Carbon dioxide
- Carbon monoxide
- Chlorobenzene
- Ethyl acetate
- Hand sanitizer (ethanol)
- Hexane
- Hydrogen
- Hydrogen peroxide
- Hydrogen sulfide
- Isobutylene
- Isopropyl alcohol
- Methane
- Mineral spirits
- Toluene
- Vinegar
- Xylene

AIR MONITORING FOR HAZARDOUS MATERIALS

- Four day course – Monday p.m. through Friday a.m.
- First 2½ days similar to this course, but more waste site discussion
- Additional topics:
  - Air sample collection
  - Direct-reading aerosol monitors
  - Portable gas chromatographs

AIR MONITORING CONSIDERATIONS

AIR MONITORING CONSIDERATIONS

- Why
- What
- How
- When
- Where
- Who

WHY and HOW?

- Health and Safety
- Compliance with Regulations/Standards
- Guidance
- Standard Operating Procedures (SOPs)

STANDARDS/REGULATIONS

Hazardous Waste Operations and Emergency Response (HAZWOPER)

- 29 CFR 1910.120 - OSHA
- 29 CFR 1926.65 - OSHA
- 40 CFR Part 311 - EPA

MONITORING REQUIREMENTS EMERGENCY RESPONSE

The individual in charge of the ICS shall

- Identify to the extent possible all hazardous substances or conditions
- Identify maximum exposure limits
- Determine through use of air monitoring whether SCBA's use can be downgraded
- Designate safety official to identify and evaluate hazards

1910.120(q)(3)

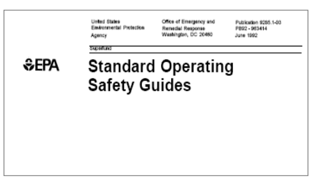
STANDARDS/REGULATIONS

- OSHA 1910.134 - Respiratory Protection
- OSHA 1910.146 - Confined Space
- OSHA 1910.1000+ - Air Contaminants
- OSHA 1926 Subpart P - Excavations
- National Contingency Plan

AIR MONITORING GUIDANCE

- National Fire Protection Association (NFPA) 472 Standard for Competence of Responders to Hazardous Materials/Weapons of Mass Destruction Incidents
- American Society for Testing and Materials (ASTM)
- National Institute for Occupational Safety and Health (NIOSH)
- Occupational Safety and Health Administration (OSHA)

AIR MONITORING GUIDANCE U.S. EPA



Publication 9285.1-03
June 1992

AIR MONITORING EPA OBJECTIVES

- Identify and quantify airborne contaminants on-site and off-site
- Track changes in air contaminants that occur over the lifetime of the incident
- Ensure proper selection of work practices and engineering controls

U.S. EPA SOSGs

AIR MONITORING EPA OBJECTIVES

- Determine the level of worker protection needed
- Assist in defining work zones
- Identify additional medical monitoring needs in any given area of the site

U.S. EPA SOSGs

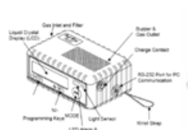
AIR MONITORING GUIDANCE U.S. EPA

- U.S. EPA Emergency Response Technical Group (ERTG)
- National Equipment List (NEL)
- Quick Start Guides (QSG)
- Equipment Operating Guides (EOG)
- www.epaosc.gov/ertg

U.S. EPA-ERTG QUICK START GUIDES

MultiRAE Plus

GENERAL INFORMATION	
Equipment Name:	MultiRAE Plus
Model:	PGM-50
Manufacturer:	RAE Systems Inc.
National Manufacturer Contact:	Telephone: 877-723-2878 E-mail: tech@raesystems.com Website: http://www.raesystems.com



NOTE: Guides are to be used by trained personnel only and DO NOT replace the manufacturer's operations or technical manuals. These guides were developed by field personnel for utilization by EPA and their contractors and are helpful in quick start-up and operations. Various limitations have been identified through the experience of the development group. Different makes, models, and updates to this equipment may change the limitations. It is recommended that calibration, maintenance, and use be recorded in a logbook. Additional product information may be found in the accompanying Equipment Operating Guides.

QUICK START GUIDES

Used on this course:

- RAE Systems' MultiRAE Plus
- Thermo TVA-1000B
- Draeger Chip Measurement System

STANDARD OPERATING PROCEDURES (SOPs)

- US EPA Environmental Response Team (ERT) SOPs
  - www.epaosc.org
  - Click Websites, then ERT logo
- Regional/Office/Site

SOPs

U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2136
PAGE: 1 of 23
REV: 0.0
DATE: 03/08/01

THE OPERATION OF THE JEROME MODELS 411 and 431 GOLD FILM MERCURY VAPOR ANALYZERS

CONTENTS

WHAT HAZARDS

- Oxygen-deficient/enriched atmospheres
- Combustible/explosive atmospheres
- Toxic atmospheres
- Radiation

AIR MONITORING: HOW

Direct-reading instruments

- "Real time" (seconds to minutes)
- Rapid response
- Generally not compound-specific
- Limited detection levels
- May not detect certain classes of compounds

U.S. EPA 1993

AIR MONITORING: HOW

Sample collection and analysis

- Sample collected and sent to laboratory for analysis
- Compound or class specific
- Greater accuracy
- Requires more time for results
- Requires additional equipment

U.S. EPA 1993

PERSONAL MONITORING

PERSONAL MONITORING USES

- Worker exposure measurement
- Warning device

AREA MONITORING

AREA MONITORING USES

- Monitor chemicals coming into area (e.g., football stadium)
- Monitor chemicals leaving an area (e.g., spill, decon line)

AREA MONITORING

METEOROLOGICAL CONSIDERATIONS

- Data uses
  - Placement of monitors
  - Input for air models
  - Calibration adjustments
- Data sources
  - On-site meteorological stations
  - Government or private organizations

U.S. EPA 1992

METEOROLOGICAL CONSIDERATIONS

- Data needed
  - Wind speed and direction
  - Temperature
  - Barometric pressure
  - Humidity

U.S. EPA 1992

INSTRUMENT CHARACTERISTICS

SELECTIVITY

- Selectivity is an instrument's ability to differentiate one chemical from others in a mixture
- Chemicals that affect an instrument's selectivity are called interferences

SENSITIVITY

Sensitivity is the least change in concentration that will register an altered reading of the instrument.

ACGIH 1989

DETECTION RANGE
UNITS

- part per billion (ppb)
  1 ppb = 1 per 1,000,000,000
- part per million (ppm)
  1 ppm = 1 per 1,000,000 = 1000 ppb
- per cent
  1 % = 1 per 100 = 10,000 ppm

DETECTION RANGE
UNITS

- mg/m^3 = milligram (mass) of chemical per cubic meter (volume) of air
- 1 mg/m^3 = 1000 $\mu g/m^3$
- gases/vapors = ppm or mg/m^3
- particulates = mg/m^3

DETECTION RANGE
EXAMPLES

- 0.5 – 2000 ppm
- 1 – 50,000 ppm (5%)
- 1 – 100% LEL (equivalent to 120 – 12,000 ppm for benzene calibrated instrument)

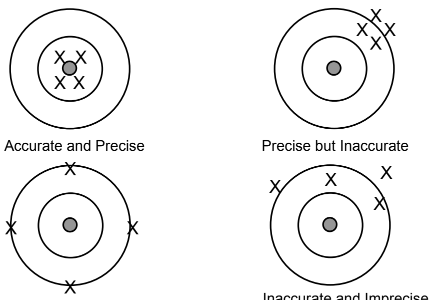
DETECTION RANGE
BENZENE

INSTRUMENT RANGE	EXPOSURE LIMIT
0.2 – 10.0	0.1
0.50 – 10.0	0.5
10.0 – 250	1
	5
	500

ACCURACY AND PRECISION

- Accuracy
  - The difference between an instrument reading and the true or correct value
- Precision
  - The grouping of data points around a calculated average
  - Measures the repeatability of data

ACCURACY AND PRECISION



U.S. DHHS 1973

RELATIVE RESPONSE

- The relationship between an instrument's reading and the actual concentration
- Calculation:

$$\text{RELATIVE RESPONSE} = \frac{\text{INSTRUMENT READING}}{\text{ACTUAL CONCENTRATION}}$$

RESPONSE FACTOR

- Based on an instrument's relative response
- Used to convert an instrument reading to an actual concentration.
- Calculation:

ACTUAL CONCENTRATION =
RESPONSE FACTOR X INSTRUMENT READING

RESPONSE FACTORS EXAMPLES

Chemical	*RAE PID**	*TVA-1000 FID*
Methane	No Response (NR)	1.0
Benzene	0.53	0.34
Vinyl chloride	2.0	1.2
Isobutylene	1.0	0.6
Acetone	1.1	0.9
Ethanol	10	1.6
Ammonia	9.7	NR

*10.6 eV lamp

CALIBRATION

- Ensures accuracy
- Response factors are based on a specific calibration gas
- Direct-reading instruments generally are calibrated to one chemical at a specific concentration

CALIBRATION
BUMP TEST

- Instrument reading is compared to known concentration in a calibration gas (certified standard).
- Instrument "passes" test if reading is within acceptable range (per manufacturer or SOP); e.g., ± 10%

CALIBRATION
FULL CALIBRATION

- Instrument reading is adjusted to known concentration in a calibration gas (certified standard)

CALIBRATION
FREQUENCY

- "A functional (bump) test or full calibration of direct-reading portable gas monitors should be made before each day's use in accordance with the manufacturer's instructions, using an appropriate test gas." (International Safety Equipment Association - ISEA 2002)
- If instrument fails a bump test, then a full calibration should be done.

CALIBRATION
FREQUENCY

- OSHA Tech Manual – before each use
- OSHA CPL 2.100 (Confined Space) – "in accordance with manufacturer's recommendations"
- RAE Systems TN-148
  - Mentions CPL 2.100 and ISEA
  - Frequency "depends"
- Your SOP

RESPONSE TIME

- The time between initial sample contact and readout of the full chemical concentration (usually seconds to minutes)
- Depends on
  - Sensor response
  - Sample line length and pump speed
  - Environmental conditions

ENVIRONMENTAL CONDITIONS

- Temperature
  - 0° to 140° F
- Humidity
  - Non-condensing
  - 0% to 90% RH
- Dust

MOBILITY

- Weight
- Power source
  - Duration
  - Replaceable?
- Durability

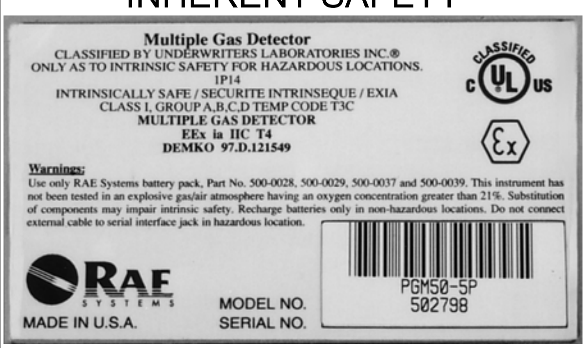
ELECTROMAGNETIC INTERFERENCE

- Electromagnetic fields (EMI) and radio frequencies (RFI)
- Sources
- Prevention
- Instrument may affect communications

RATING SYSTEMS

- Dust/Water – IEC 60529 and NEMA
  - IP-55 (MultiRAE Plus): protected against dust, protected against low pressure jets of water from all directions
- Impact – EN 50102
  - IK07: Resistant against impact from an object of 500 grams from a distance of 40 cm
- EMI – CE marking on compatibility

INHERENT SAFETY



EASE OF OPERATION

- How easy is it to operate the controls?
- How easy is it to learn to operate?
- How many steps must be performed before an answer is obtained?
- How easy is it to repair?

OXYGEN MONITORS, COMBUSTIBLE GAS INDICATORS AND SPECIFIC CHEMICAL MONITORS

HAZARDS

- Oxygen-deficient/oxygen enriched atmospheres
- Combustible/explosive atmospheres
- Toxic atmospheres
- Radiation

OXYGEN MONITORING INFORMATION

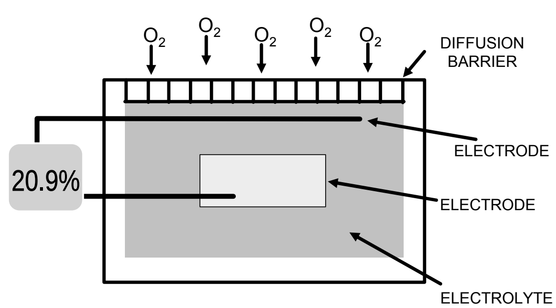
- Type of respirator needed
- Flammability risk
- Sufficient oxygen for other instruments
- Possible presence of contaminants at high concentrations

WHAT IF IT'S DISPLACEMENT?

OXYGEN READING	CONTAMINANT CONCENTRATION
20.8%	0% (0 ppm)
20.7%	0.5% (5000 ppm)
20.6%	1.0% (10,000 ppm)
19.5%	6.5% (65,000 ppm)

Note: Air is about 4 parts N_2 to 1 part O_2

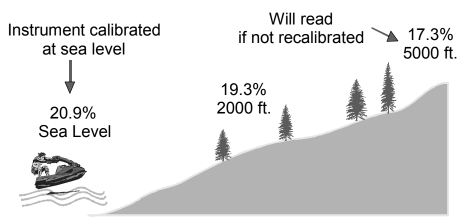
OXYGEN SENSOR



OXYGEN MONITORING CONSIDERATIONS

- Life span
- Operating temperature
- Interfering gases
- Atmospheric pressure

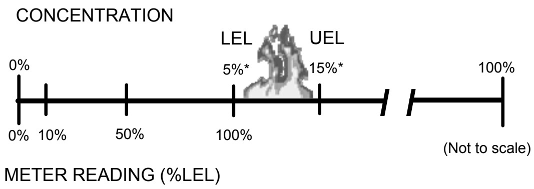
OXYGEN MONITORS EFFECTS OF ALTITUDE



COMBUSTIBLE GAS INDICATORS INFORMATION

- Risk of fire or explosion
- Possible presence of contaminants at high concentrations

COMBUSTIBLE GAS INDICATORS INSTRUMENT READING vs. CONCENTRATION



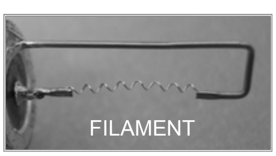
NOTE: * limits for methane

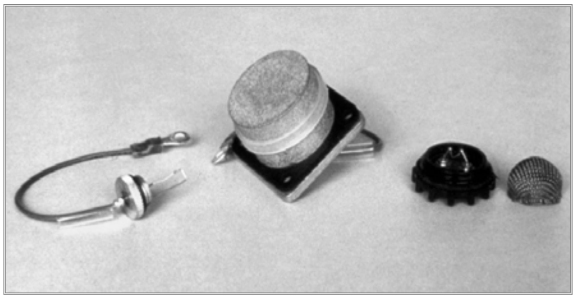
LEL = lower explosive limit
UEL = upper explosive limit

COMBUSTIBLE GAS SENSORS

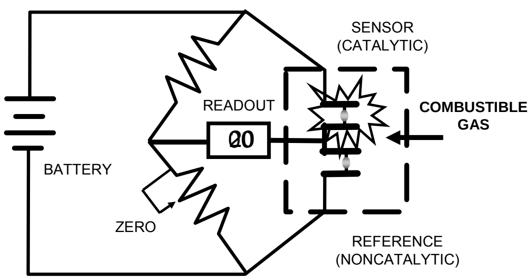
- Catalytic combustion (CC)
- Infrared (IR) absorption
- Metal-oxide semiconductor (MOS)

COMBUSTIBLE GAS INDICATORS CATALYTIC SENSORS

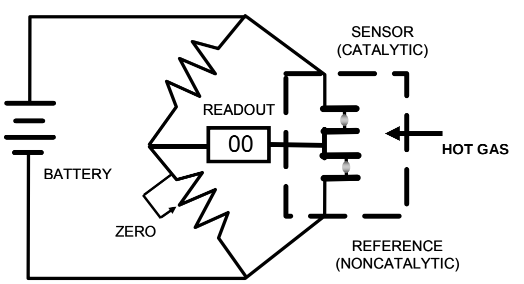




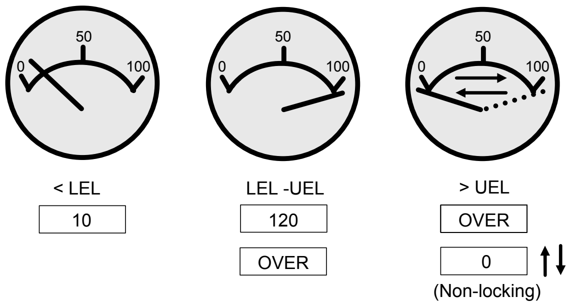
CATALYTIC COMBUSTION COMBUSTIBLE GAS



CATALYTIC COMBUSTION HOT GAS



EXAMPLES OF READINGS



COMPARISON OF LEL READINGS WITH ACTUAL CONCENTRATIONS

BENZENE LEL = 1.2%

For an instrument calibrated to benzene measuring benzene:

LEL	100%	=	1.2%	(12,000 ppm)
	50%	=	0.6%	(6,000 ppm)
	25%	=	0.3%	(3,000 ppm)
	10%	=	0.12%	(1,200 ppm)
	1%	=	0.012%	(120 ppm)

METAL-OXIDE SEMICONDUCTORS (MOS)

- Metal-oxide coating on a ceramic substrate wrapped around a wire
- Contaminant alters conductivity by removing oxygen
- Change in current is proportional to the amount of contaminant present
- Also called "solid-state" sensor

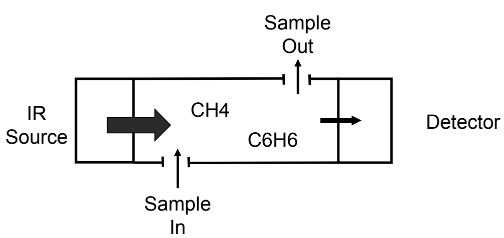
MOS EXAMPLES

MSA Orion-G

SCOTT LeakAlert

CGIs INFRARED ABSORPTION

Chemical absorbs infrared light



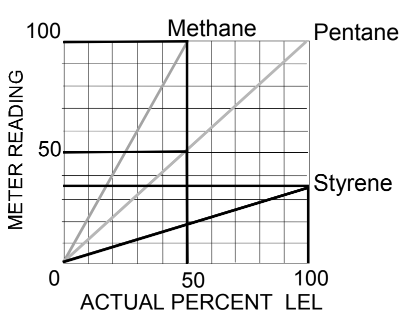
CGI READOUTS

- Catalytic combustion
  - 0-100% LEL
  - 0-10% LEL
  - ppm (supersensitive)
- IR and MOS
  - Not affected by the UEL
  - Readings can be %LEL, ppm, or % concentration
- ppm readouts for "toxic" concentrations

CGI CONSIDERATIONS

- Oxygen requirements (CC, MOS)
- Sensor poisons (CC)
- Temperature (CC, MOS)
- Saturation (MOS, CC)
- False negatives (IR, CC)
- False positives (MOS)
- Relative response (All)

CGI RELATIVE RESPONSE



Based on MSA Information

TOXIC ATMOSPHERE MONITORING

Reasons for toxic atmosphere monitoring

- Identify chemicals and their concentrations
- Evaluate exposures to workers or the public
- Determine exposure controls
- Select proper PPE

TOXIC ATMOSPHERE MONITORS

- Specific chemical monitors
- Total vapor monitors (broad band)
- Gas chromatograph
- Aerosol monitor

SPECIFIC CHEMICAL MONITORS

- Designed to monitor/detect a specific chemical
- Common types are
  - Electrochemical sensors
  - MOS
  - Infrared
  - Colorimetric indicators
  - Mercury

ELECTROCHEMICAL SENSORS

- Similar principle to how oxygen sensor works
- Electrolyte and electrodes determine what it detects
- Common types
  - Carbon monoxide
  - Hydrogen sulfide
  - Hydrogen cyanide

ELECTROCHEMICAL SENSORS

Dräger Pac® 7000

GfG Micro IV

ToxiRAE 3

ELECTROCHEMICAL CONSIDERATIONS

- Life span
- Operating temperature
- Atmospheric pressure
- Interferences/cross sensitivities

CROSS-SENSITIVITIES

- CO
  - 100 ppm H_2 ► 100 ppm
  - 100 ppm isobutylene ► 4 ppm*
- H_2S
  - 5 ppm SO_2 ► 4 ppm
  - 5 ppm phosphine ► 4 ppm
- HCN
  - H_2S: not recommended
  - 5 ppm SO_2 ► 8 ppm

*With filter
Source: Rae Systems TN-114

INFRARED

- Same principle as discussed earlier
- In this case, a wavelength that is absorbed by the specific chemical is used
- Examples
  - Carbon dioxide
  - Ethylene oxide

MOS

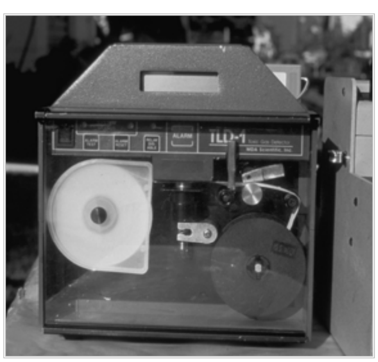
- Same principle as discussed earlier
- However, the type of metal, coating or temperature control may be used to make the sensor more specific
- Examples
  - carbon monoxide
  - nitrogen oxides
  - sulfur dioxide

MULTI-GAS MONITOR

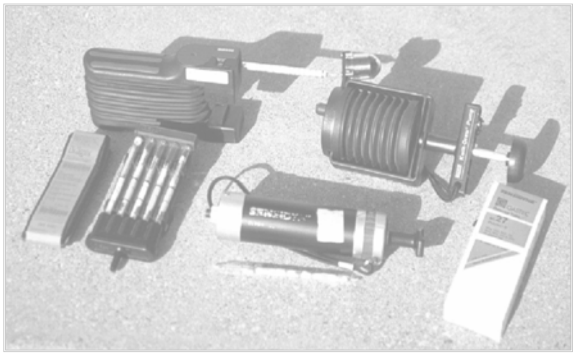
COLORIMETRIC INDICATORS

Contaminant reacts with a chemical on a tape, badge, or tube and causes a color change.

SINGLE POINT MONITOR (SPM)



DETECTOR TUBE SYSTEMS



SIMULTANEOUS TEST-SETS

- Simultaneous Test-Sets
  - Inorganic gases (2 sets)
  - Organic vapors
  - Clandestine lab
  - Civil defense (4 sets)
  - Conductive Compounds (fire)
  - Container Aeration I (fire)
  - Fumigation

COLORIMETRIC INDICATORS CONSIDERATIONS

- Life span
- Humidity
- Temperature
- Interferences

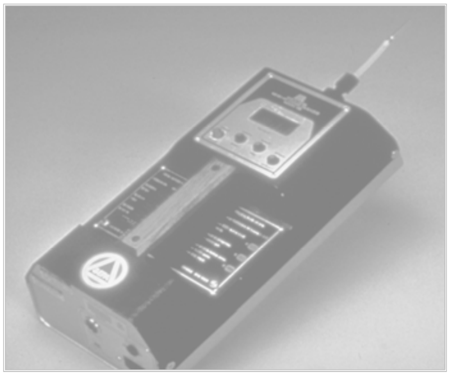
MERCURY DETECTORS

- Gold film
- Atomic absorption (AA)

JEROME: GOLD FILM

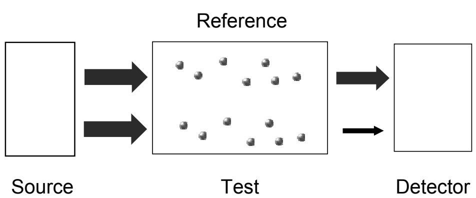
- Mercury reacts with gold film and increases the electrical resistance of the film
- May become saturated
- Regeneration requires AC power
- Factory calibrated but monthly functional test requires mercury
- Interferences: cigarette smoke, some cleaners, high humidity, temperature variations, dirty filters

JEROME



LUMEX: AA

Mercury absorbs certain spectrum of light



LUMEX

LUMEX

- Not for high concentrations (>50 mg/m^3)
- Heavy
- Temperature-sensitive; needs time to stabilize
- Dusty environments and moisture
- Fragile instrument
- Not intrinsically safe

DETECTION LIMITS AND ACTION LEVELS

Instrument	**Detection Limit (mg/m^3)**
Jerome (Gold film)	0.003
Lumex (AA)	0.000002
Action Level	**Concentration (mg/m^3)**
IDLH	10.0
ACGIH TLV	0.025
U.S. EPA Residential Cleanup Goal	0.0003

Modified from U.S. EPA EOG

TOTAL VAPOR INSTRUMENTS

TOTAL VAPOR INSTRUMENTS

Instruments using detectors that respond to a wide variety of chemicals and give readings in the parts per million (ppm)/parts per billion (ppb) range.

FOR WHAT ARE TOTAL VAPOR INSTRUMENTS USED?

- Site characterization
- Exposure monitoring
- Sample screening

SITE CHARACTERIZATION

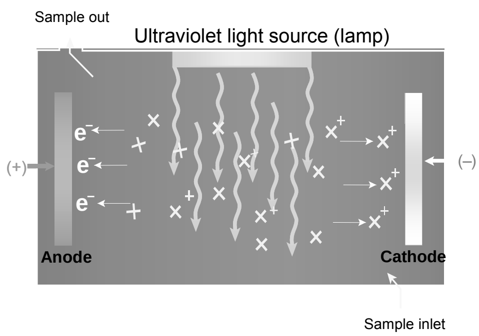
EXPOSURE MONITORING

SAMPLE SCREENING

TYPES OF TOTAL VAPOR INSTRUMENTS

- Photoionization detector (PID)
- Flame ionization detector (FID)
- Supersensitive combustible gas indicator (CGI)
- Metal-oxide semiconductor (MOS)
- Infrared detector (IR)

PHOTOIONIZATION



PHOTOIONIZATION

$$R + h\nu \longrightarrow R^{+} + e^{-}$$

R = chemical absorbing UV
h(nu) = photon with energy ≥ ionization potential (IP) of chemical

NOTE: This ionization process is non-destructive

IONIZATION POTENTIALS

LAMP ENERGIES IN ELECTRON VOLTS (eV)

CO (14.0)
HCN (13.9)
Methane (13.0)
HCl (12.7)
Water (12.6)
Oxygen (12.1)

11.7 →
Chlorine (11.5)
Propane (11.1)
Trichloroethane (11.0)

10.6 →
H_2S (10.5)
Hexane (10.2)
Ammonia (10.1)
Acetone (9.7)

9.5 →
TCE (9.5)
Benzene (9.2)
Toluene (8.8)

IONIZATION POTENTIAL

Chemical	*IP (eV)*
Carbon Dioxide	13.8
Propane	11.1
Vinyl Chloride	10.0
Acetone	9.7

PHOTOIONIZATION DETECTOR

11.7 eV lamp *vs*. 10.6 eV lamp

- 11.7 wears out faster than 10.6
- 11.7 is more susceptible to humidity
- 10.6 may provide better response to chemicals it can detect
- 10.6 may be less expensive

PHOTOIONIZATION DETECTOR CONSIDERATIONS

- Lamp energy/chemical IP
- Dust/humidity
- High methane or CO_2
- Low oxygen
- Electromagnetic interferences
- Lamp aging
- Relative response
- High concentrations

PHOTOIONIZATION DETECTOR RESPONSE FACTORS

Chemical	*Response Factor* (10.6 / 11.7)*	*IP*
m-Xylene	0.43 / 0.40	8.56
Benzene	0.53 / 0.6	9.25
Phenol	1.0 / 0.9	8.51
Isobutylene	1.0 / 1.0	9.25
Acetone	1.1 / 1.4	9.71
Hexane	4.3 / 0.54	10.13
Ammonia	9.7 / 5.7	10.16

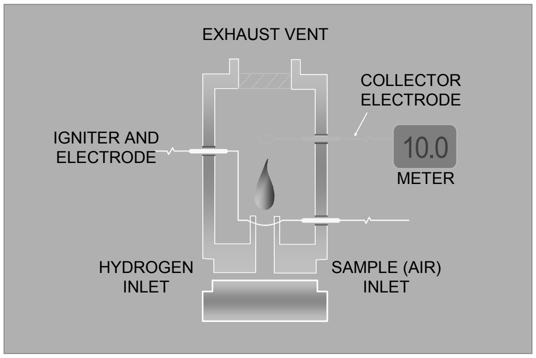
** RAE Systems calibrated to isobutylene; (#) are lamp energies in eV*

PHOTOIONIZATION DETECTOR HIGH CONCENTRATION EFFECTS

Actual Concentration (ppm)	*Instrument Reading*	*Response Factor*
10	10	1.00
50	50	1.00
100	100	1.00
250	215	1.16
500	364	1.37
1000	557	1.80
2000	759	2.64

** TVA - 1000 B Response Factors (isobutylene)*

FLAME IONIZATION DETECTOR



FLAME IONIZATION

$$RH + O_2 \xrightarrow{FLAME} RHO^+ + e^- \longrightarrow CO_2 + H_2O$$

NOTE: This ionization process is destructive

FLAME IONIZATION CONSIDERATIONS

- Primarily organics detected
- Methane detected
- Hydrogen gas needed
- Flameout
  - Low O_2
  - High concentrations
  - Cold temperature
- Electromagnetic interferences
- Relative response

FLAME IONIZATION RESPONSE FACTORS*

Chemical	Response Factor*
Benzene	0.34
Propane	0.62
Methane	1.0
Methanol	3.8
Trichloroethylene	1.2
Freon-12	4.2
Formaldehyde	7.3

** TVA - 1000B calibrated to methane*

PID EXAMPLES

Photovac 2020 *Combo*PRO

MiniRAE 3000 and ppbRAE 3000

MSA Sirius®

MultiRAE PGM-50

(PID / LEL / O_2 / TOXICS)

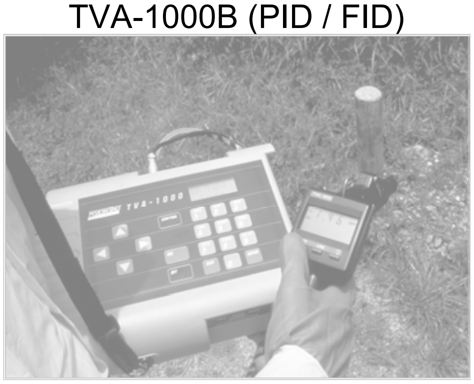
AreaRAE

(PID / LEL / O_2 / TOXICS)

Drager X-am 7000

(PID / LEL / O2 / TOXICS)

THERMO ENVIRONMENTAL
TVA-1000B (PID / FID)



PHOTOVAC MicroFID

CONCLUSION CONSIDERATIONS

- What the instrument can detect
- Survey, not identification
- Interpretation of data
- Logistical factors
- Environmental factors
- Special features

EXPOSURE LIMITS AND ACTION GUIDES

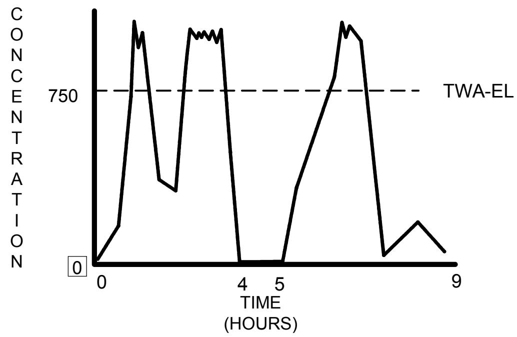
CONSIDERATIONS

- Designed for whom?
  - Worker
  - Public
- Time frame?
  - Long term
  - Short term/acute
- Effects?
  - No effect level
  - Risk level

OCCUPATIONAL EXPOSURE LIMIT (OEL)

- An exposure limit intended for workers
- Based on:
  - healthy population
  - 8- to 10-hour work day (40-hour week)
  - working lifetime

TIME-WEIGHTED AVERAGE (TWA)



TWA CALCULATION

Exposures: 1500 ppm for 1 hour
500 ppm for 3 hours
200 ppm for 4 hours

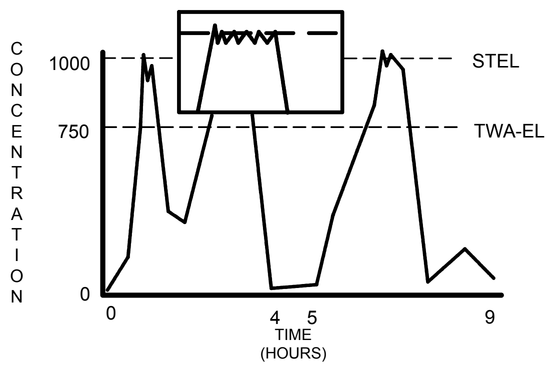
$$\frac{(1\ \text{hr})(1500\ \text{ppm}) + (3\ \text{hrs})(500\ \text{ppm}) + (4\ \text{hrs})(200\ \text{ppm})}{8\ \text{hrs}} =$$

$$\frac{1500\ \text{ppm} + 1500\ \text{ppm} + 800\ \text{ppm}}{8} = 475\ \text{ppm}$$

SHORT-TERM EXPOSURE LIMIT (STEL)

- Usually refers to a 15-minute TWA that should not be exceeded at any time during a work day
- Other restrictions like number of excursions or time between excursions may be specified
- Supplements TWA

STEL

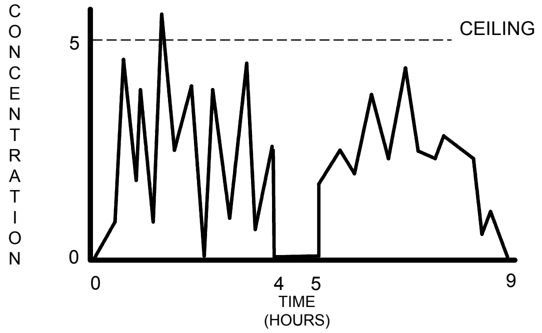


CEILING

- The limit that shall at no time be exceeded
- If instantaneous monitoring is not feasible, then the ceiling shall be assessed as a 15-minute TWA exposure which shall not be exceeded at any time during a work day

29 CFR 1910.1000 (a)

CEILING



PEAK EXPOSURE LIMIT

- A peak concentration limit is the concentration above the acceptable ceiling that shall not be exceeded for a specified time period
- Example: Trichloroethylene

Ceiling = 200 ppm
Peak = 300 ppm for 5 minutes in any 2 hours

29 CFR 1910.1000 (b)(2); 29 CFR 1910.1000 Table Z-2

OSHA EXPOSURE LIMITS

The Occupational Safety and Health Administration (OSHA) exposure limits are called permissible exposure limits (PELs) and are found in 29 CFR 1910, Subpart Z.

OSHA EXPOSURE LIMITS

- Enforceable requirements
- Based on 1968 TLVs and American National Standards Institute (ANSI)
- Found in 29 CFR 1910.1000 and specific chemical standards
- Include TWA, STELS, ceilings, and peaks

NIOSH EXPOSURE LIMITS

The National Institute for Occupational Safety and Health's (NIOSH) exposure limits are called recommended exposure limits (RELs) and are found in the *NIOSH Recommendations for Occupational Safety and Health Standards.*

NIOSH EXPOSURE LIMITS

- Recommended exposure limits
- Enforceable by reference
- Rationale in criteria documents
- Include 10-hr TWAs, STELs, and ceilings

ACGIH EXPOSURE LIMITS

The American Conference of Governmental Industrial Hygienists (ACGIH) uses Threshold Limit Values (TLVs®) found in the *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices.*

ACGIH EXPOSURE LIMITS

- Guidelines
- Enforceable by reference
- Yearly booklet
- Separate documentation
- Include TWAs, STELs, and ceilings

AIHA EXPOSURE LIMITS

The American Industrial Hygiene Association (AIHA) publishes exposure limits called *Workplace Environmental Exposure Level Guides (WEELs).*

AIHA EXPOSURE LIMITS

- Guidelines
- Yearly updates
- Documentation
- Include TWAs, short-term TWAs, and ceilings

EXAMPLES OF EXPOSURE LIMITS[1]

CHEMICAL / SOURCE	ACETONE (ppm)	BENZENE (ppm)	LEAD (mg/m^3)
OSHA	1000	1 5 (STEL)	0.05
NIOSH	250	Ca, 0.1 1 (STEL)	0.05
ACGIH	500 750 (STEL)	0.5, A1 2.5 (STEL)	0.05, A3
AIHA	----	----	----

[1] TWA unless otherwise noted

EXAMPLES OF EXPOSURE LIMITS

CHEMICAL / SOURCE	TOLUENE (ppm)	GASOLINE (ppm)	BENZALDEHYDE (ppm)
OSHA			
NIOSH			
ACGIH			
AIHA			

EXAMPLES OF EXPOSURE LIMITS

CHEMICAL / SOURCE	TOLUENE (ppm)	GASOLINE (ppm)	BENZALDEHYDE (ppm)
OSHA	200 C300; Peak 500	----	----
NIOSH	100 150 (STEL)	Ca LOQ = 15 ppm	----
ACGIH	20, A4	300, A3 500 (STEL)	----
AIHA	----	----	2 4 (STEL)

EXPOSURE LIMITS 1910.120 HIERARCHY

- OSHA PELs
- NIOSH RELs (1986)
- ACGIH TLVs (1987-88)

EXPOSURE LIMITS APPLICATIONS

- Exposure control
  - Engineering controls
  - Work practices
  - Personal protective equipment
- PPE selection during site characterization
- Medical monitoring determination

EVALUATION OF A MIXTURE

$$E_m = C_1/L_1 + C_2/L_2 + \ldots C_n/L_n$$

E_m is the equivalent exposure for the mixture

C is the concentration of a particular contaminant

L is the exposure limit for that contaminant

29 CFR 1910.1000 (d)(2)(i)

EVALUATION OF A MIXTURE EXAMPLE

Chemical A: C = 500 ppm, L = 750 ppm (TWA)
Chemical B: C = 200 ppm, L = 500 ppm (TWA)
Chemical C: C = 50 ppm, L = 200 ppm (TWA)

$E_m = (500/750) + (200/500) + (50/200)$
$E_m = 0.67 + 0.40 + 0.25$
$E_m = 1.32$

EVALUATION OF A MIXTURE

- E_m should not exceed 1
- The calculation applies to chemicals where the effects are the same and are additive
- Do not mix TWAs, STELs, and ceilings

AIRBORNE EXPOSURE LIMITS (AELs)

- Usually refers to exposure limits for chemical warfare agents
- Types
  - General population limit (GPL)
  - Worker population limit (WPL)
  - STEL (Workers)
  - IDLH (Workers)

EXAMPLES OF AELs

LIMIT \ CHEMICAL	GA, GB (mg/m^3)	H, HD (mg/m^3)	VX (mg/m^3)
GPL (24 hr)	0.000001	0.00002	0.0000006
WPL (8 hr)	0.00003	0.0004	0.000001
STEL (15 min)	0.0001	0.003	0.00001
IDLH	0.1	0.7	0.02

CDC 2003, 2004

ACTION LEVEL or ACTION GUIDE

The chemical concentration or instrument reading at which a specific action should be taken.

ACTION LEVEL OSHA

- In the OSHA standards for specific chemicals (e.g., benzene) the action level is one-half the PEL
- Exceeding the action level may trigger requirements, such as additional air monitoring or medical surveillance

ACTION GUIDES
EPA GUIDANCE

- Standard Operating Safety Guides (SOSGs) (U.S. EPA 1992)
- Compliance with OSHA

EPA ACTION GUIDES
COMBUSTIBLE GAS INDICATOR

LEVEL	ACTION
<10% LEL (<5%)*	Continue monitoring with caution
10-25% LEL	Continue monitoring, but with extreme caution
>25% LEL (>5%)*	Explosion hazard! Withdraw from area immediately.

*Confined space

EPA ACTION GUIDES
OXYGEN CONCENTRATION

LEVEL	ACTION
<19.5%	Monitor wearing SCBA
19.5-25%	Continue monitoring, with caution. SCBA not needed based only on oxygen content
>25%	Discontinue monitoring. Fire potential! Consult specialist.

OSHA IDLH

". . . means an atmospheric concentration of any toxic, corrosive, or asphyxiant substance that poses an immediate threat to life or would cause irreversible or delayed adverse health effects or would interfere with an individual's ability to escape from a dangerous atmosphere."

29 CFR 1910.120 (a)

NIOSH IDLH

An IDLH exposure condition is a condition "that poses a threat of exposure to airborne contaminants when that exposure is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment."

U.S. DHHS 1987

IDLH EXAMPLES

CHEMICAL	IDLH
ACETONE	2500 ppm (10% LEL)
BENZENE	Ca (500 ppm)
LEAD	100 mg/m^3 (as lead)
TETRAETHYL LEAD	40 mg/m^3 (as lead)
BENZALDEHYDE	Not Available

U.S. DHHS 1997

PUBLIC EXPOSURE LIMITS

- Intended to prevent effects or predict effects in general public
- Types
  - Ambient air quality standards
  - Risk assessment numbers
  - Emergency planning guides

EMERGENCY PLANNING GUIDELINES

- Intended to assist in planning
- Use to anticipate human adverse health effects caused by exposure to toxic chemicals
- Not to be used as safe limits for routine operations
- Designed for populations more sensitive than workers, but not necessarily most sensitive

ACUTE EXPOSURE GUIDELINE LEVELS (AEGLs)

- Published by National Advisory Committee for Acute Exposure Guideline Levels for Hazardous Substances (US EPA)
- 3 effect levels
- Up to 6 time periods
- www.epa.gov/oppt/aegl/chemlist.htm

AEGL-1

The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic, non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

AEGL-2

The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects, or an impaired ability to escape.

AEGL-3

The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

EXAMPLE OF AEGL FOR AMMONIA

LEVEL / TIME	AEGL-1 (ppm)	AEGL-2 (ppm)	AEGL-3 (ppm)
10 minutes	30	220	2700
30 minutes	30	220	1600
60 minutes	30	160	1100
4 hours	30	110	550
8 hours	30	110	390

EMERGENCY RESPONSE PLANNING GUIDELINES (ERPGs)

- Published by AIHA
- ". . . intended for application by persons trained in emergency response planning."
- ". . . not to be used as safe limits for routine operations."
- 3 effect levels
- 1-hour time frame

AIHA 2004

ERPG-1

The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing more than mild, transient adverse health effects or without perceiving a clearly defined objectionable odor.

ERPG-2

The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action.

ERPG-3

The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

EXAMPLES OF ERPGs

LEVEL / CHEMICAL	ERPG-1 (ppm)	ERPG-2 (ppm)	ERPG-3 (ppm)
AMMONIA	25	150	750
BENZENE	50	150	1000
HCl	3	20	150
TOLUENE	50	300	1000

TEMPORARY EMERGENCY EXPOSURE LIMITS (TEELs)

- Developed by US DOE
- Supplements ERPGs
- Definition almost the same
- ". . . be calculated as the peak 15-minute time-weighted average concentration."
- One additional level

TEEL-0

The maximum concentration below which most people will experience no appreciable risk of health effects.

PROTECTIVE ACTION CRITERIA (PACs)

- Database developed by US DOE
- Four levels given
- Based on AEGLs, ERPGs and TEELs (in that order)
- http://orise.orau.gov/emi/scapa/teels.htm

EXAMPLES OF PACs

LEVEL \ CHEMICAL	VINYL ACETATE (ppm)	BENZENE (ppm)	BENZALDEHYDE (ppm)
TEEL-0	5	1	2
PAC-1	5_E	52_A	4
PAC-2	75_E	800_A	4
PAC-3	500_E	4000_A*	150

*A = 60-minute AEGL; E = ERPG; * = >10%LEL, <50% LEL*

PROVISIONAL ADVISORY LEVELS (PALs)

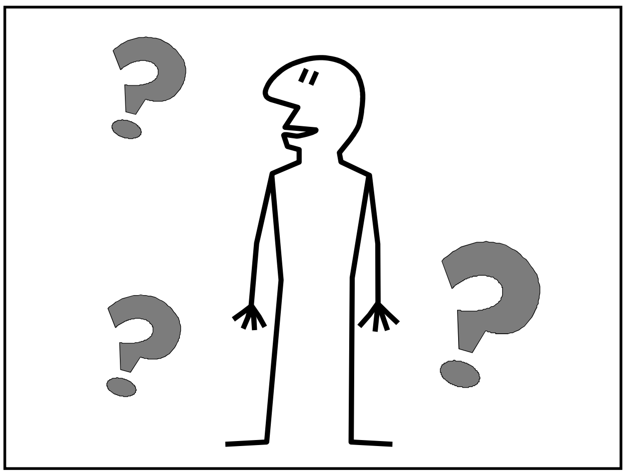
- Three time periods
- Three effect levels
- Bridges gap (i.e., subchronic) between acute numbers and chronic public health numbers
- Air and drinking water; re-entry/resumed use
- Sensitive/susceptible populations - public
- www.epa.gov/NHSRC (numbers upon request)

PROVISIONAL ADVISORY LEVELS (PALs)

- Times
  - Acute: 24-hour
  - Short-term: >1 to 30 days
  - Long-term: >30 days to 2 years
- Levels
  - PAL 1: mild, transient, reversible effect
  - PAL 2: serious, possible irreversible
  - PAL 3: severe effect/lethality

CONSIDERATIONS

- Designed for whom?
  - Worker
  - Public
- Time frame?
  - Long term
  - Short term/acute
- Effects?
  - No effect level
  - Risk level



FIELD ANALYTICAL TECHNOLOGIES

STUDENT PERFORMANCE OBJECTIVES

1. Describe the principle of operation of field analytical technologies currently utilized to evaluate chemicals in air.
2. Give an example of a field instrument that uses each technology.

FIELD ANALYTICAL TECHNOLOGIES

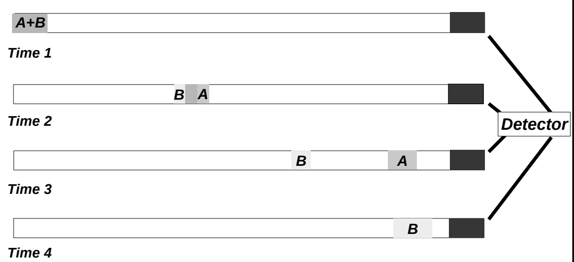
- Gas chromatography
- Mass spectroscopy
- Optical sensing

GAS CHROMATOGRAPHY OPERATION PRINCIPLE

Gas chromatography is a technique for separating volatile substances by percolating a gas stream over a stationary phase.

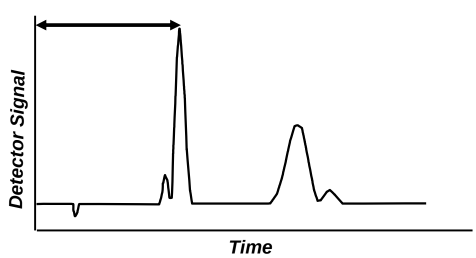
SOURCE: Basic Gas Chromatography, McNair & Bonelli 1968

CHROMATOGRAPHY

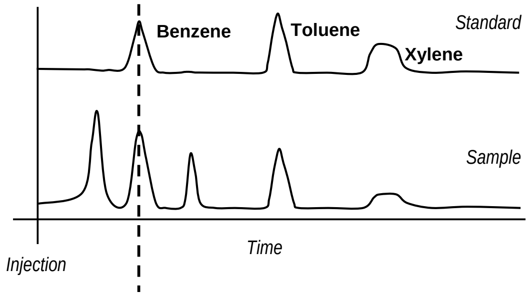


RETENTION TIME

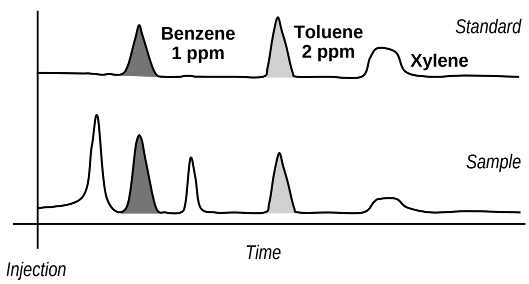
Retention time is the time from sample injection to peak maxima.



PEAK COMPARISON IDENTIFICATION



PEAK COMPARISON QUANTITY



RETENTION TIME FACTORS

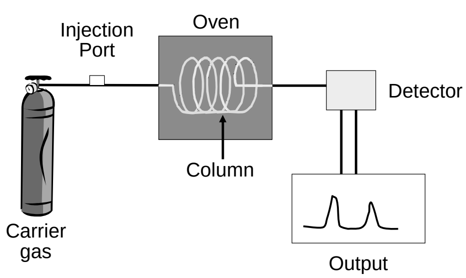
- Column type (packing)
- Column length
- Column temperature
- Carrier gas flow rate

EFFECT OF COLUMN TYPE AND TEMPERATURE

Chemical	Temperature (°C)	Retention Time (minutes:seconds)	
		Column A	Column B
Benzene	0	1:24	1:40
	40	0:25	0:30
Acetone	0	1:28	0:35
	40	0:25	0:15

SOURCE: The Foxboro Company Chromatographic Column Guide for Century Organic Vapor Analyzer, 1989

GAS CHROMATOGRAPH COMPONENTS



CARRIER GAS

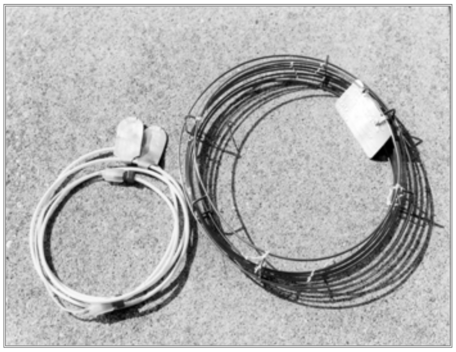
CARRIER GAS DESIRED CHARACTERISTICS

- Suitable for detector
- High purity
- Inert

INJECTION PORT SYRINGE

INJECTION PORT SAMPLE LOOP

COLUMNS

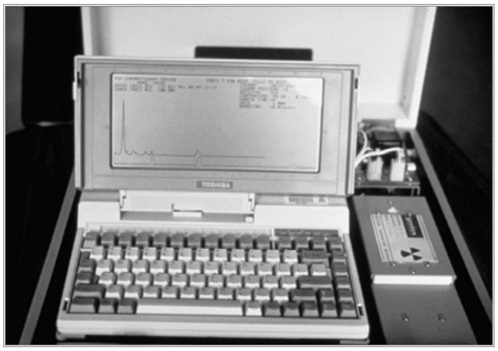


DETECTOR

DETECTORS USED IN PORTABLE GCs

- Photoionization – PID (IP)
- Flame ionization – FID (organics)
- Electron capture – ECD (halogenated)
- Thermal conductivity – TCD (universal)
- Flame photometric – FPD (pesticides, chemical agents)
- Mass spectrometer – MS

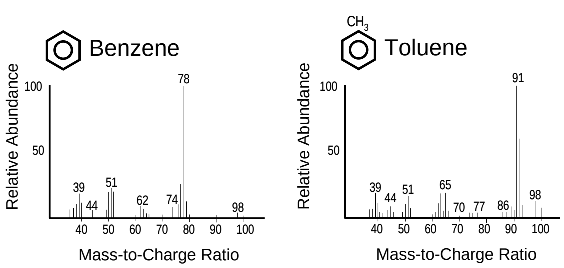
OUTPUT



MASS SPECTROMETERS OPERATION PRINCIPLE

- Chemical exposed to electrons
- Molecule or fragments are ionized
- Ions separated by magnetic field
- Separation based on speed and mass-to-charge ratio
- Detector capable of providing additional chemical identification beyond retention time

MASS SPECTRA



TRACE ATMOSPHERIC GAS ANALYZER (TAGA)

Source: D. Mickunas, U.S. EPA

VIDEO

UPDATE

David Mickunas

919-541-4191

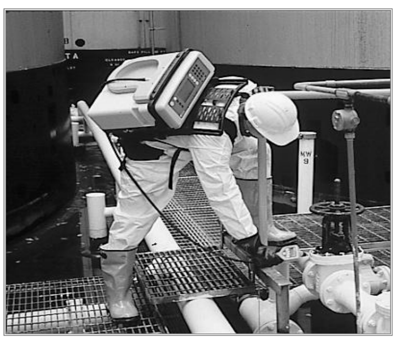
Mickunas.Dave@epa.gov

May 5 Mississippi and Alabama TAGA Results above Detection Limit

Date_Time	Benzene Avg. (ppb)	Toluene Avg. (ppb)	Xylene Avg. (ppb)	Latitude	Longitude
5/5/2010 23:52:48	0.308	5.194	0.152	30.405516	-88.483898
5/5/2010 23:54:40	0.912	0.406	0.511	30.390076	-88.508266
5/5/2010 23:54:41	1.208	3.125	2.786	30.389982	-88.508413
5/5/2010 23:54:42	2.501	5.695	4.384	30.389887	-88.508561
5/5/2010 23:54:43	2.120	6.601	3.579	30.389792	-88.508711
5/5/2010 23:54:44	1.338	2.489	1.957	30.389696	-88.508862
5/5/2010 23:54:45	1.397	2.692	1.770	30.389599	-88.509014
5/5/2010 23:54:46	0.604	1.042	0.927	30.389502	-88.509166
5/5/2010 23:54:47	0.474	2.313	1.154	30.389406	-88.509315
5/5/2010 23:54:48	0.912	1.217	1.273	30.389311	-88.509463
5/5/2010 23:54:49	1.397	2.083	0.946	30.389218	-88.509609
5/5/2010 23:54:50	0.793	2.516	0.992	30.389125	-88.509754
5/5/2010 23:54:51	0.485	3.733	1.151	30.389031	-88.509900
5/5/2010 23:54:52	1.030	0.406	1.040	30.388937	-88.510047
5/5/2010 23:54:53	0.923	1.271	0.826	30.388843	-88.510197
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

"PORTABLE" MASS SPECTROMETER

INFICON HAPSITE®



Source: Evaluation Report, CalEPA

OPTICAL SENSING

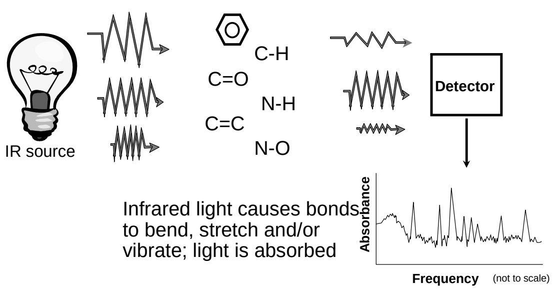
- Open-Path Fourier Transform Infrared (OP-FTIR)
- Ultra-Violet Differential Optical Absorption Spectra (UV-DOAS)
- Differential absorption light detection and ranging (DIAL-LIDAR)
- Raman Spectroscopy
- Tunable Diode Lasers (TDLs)

http://www.cluin.org/programs/21m2/openpath/default.cfm

INFRARED SPECTROSCOPY (IR)

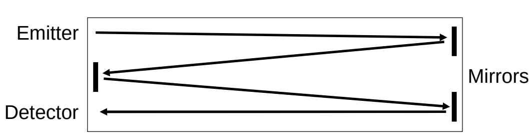
Infrared spectroscopy technology is based on the absorption of infrared radiation by certain types of bonds within a molecule.

INFRARED SPECTROSCOPY (IR)



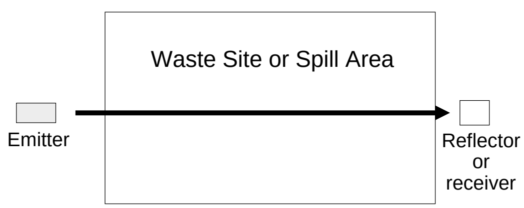
INFRARED SPECTROSCOPY (IR)

- Works well with liquids or solids because of molecule density
- Air monitoring requires longer path length of IR light

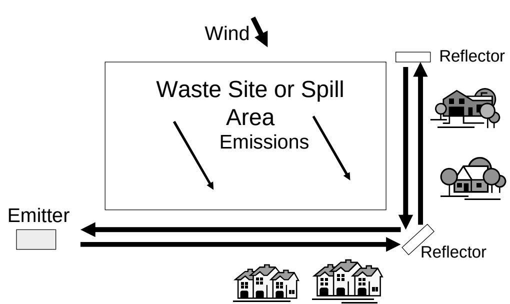


Thermo SaphIRe®

OPEN-PATH FTIR MEASURING OUTSIDE THE "BOX"



OPEN-PATH FTIR



OPEN-PATH FTIR

OPEN-PATH FTIR

PROGRAM ASPECT

Airborne Spectral Photometric Environmental Collection Technology

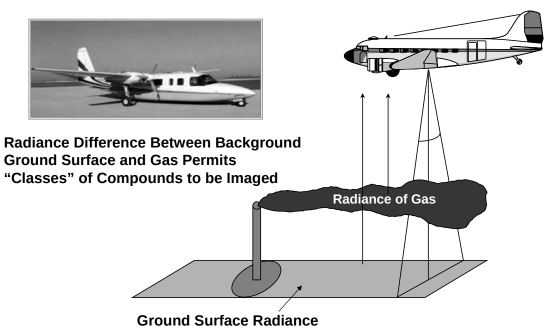
The primary mission of Program ASPECT is to provide chemical specific information to the first responder in a form that is timely, useful, and compatible with existing infrastructures.

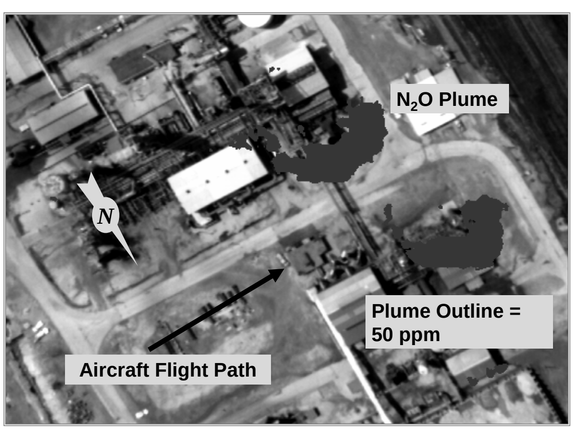
ASPECT can be activated by a phone request through the respective EPA Emergency Response Regional Office.

ASPECT'S BIRTHPLACE THE SAFEGUARD PROJECT

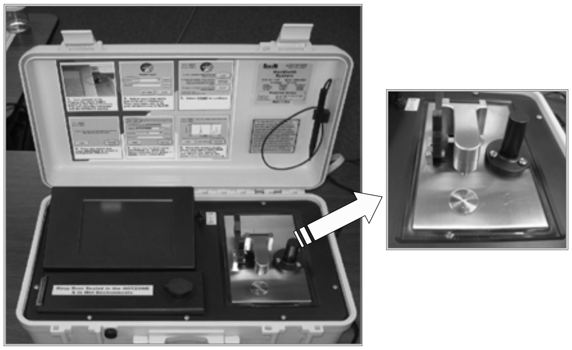
- SAFEGUARD began as a standoff chemical detection research program with two primary goals:
  - Development of a reliable battlefield chemical agents detection system
  - Identification and assessment of developing chemical agent threats

CONCEPT





HazMatID



GasID

OPTICAL SENSING

- Advantages
  - Remote monitoring
  - Easily transported
  - Cover a path or area, not just a point
- Disadvantages
  - Weather conditions
  - Long setup time
  - Signal loss over long distances

FIELD ANALYTICAL TECHNOLOGIES

- Taking "laboratory" technology into the "field"
- Why?
  - Quick identification
  - Remote sensing possible
- Quality of data can be as good as fixed laboratory
  - www.epa.gov/etv

CHEMICAL WARFARE AGENT (CWA) DETECTION

OBJECTIVES

- Describe the principle of operation for specific CWA detectors
- Identify instrumentation used for CWA detection
- List considerations for the detectors
- Identify three sources of information on CWA instruments

REFERENCES

- U.S. Army Edgewood Chemical Biological Center (ECBC)
- Domestic Preparedness Program Evaluations
- www.ecbc.army.mil/hld/ip/reports.htm
- 25 instruments evaluated as of December 2006

ECBC EVALUATION

- Minimum detectable level
- False positives
- False negatives
- Humidity effects
- Temperature effects

REFERENCES

- U.S. Department of Justice, National Institute of Justice
- *Guide to the Selection of Chemical Agent and Toxic Industrial Material Detection Equipment for Emergency First Responders*
- www.ojp.usdoj.gov/nij/pubs.htm
- Data based on market survey

NIJ PARAMETERS

- Chemical/biological agents detected
- Toxic Industrial Materials (TIMs) detected
- Detection state
- Sensitivity
- Resistance to interferents

NIJ PARAMETERS

- Start-up time
- Response time
- Alarm Capability
- Physical parameters
- Logistical parameters
- Special requirements

U.S. EPA HOMELAND SECURITY RESEARCH CENTER

U.S. EPA HOMELAND SECURITY RESEARCH CENTER

Table 5-1. Summary Results of CWA Vapor Testing

Technology	CWA	Test Condition[a,b]			
		Base	Base + Int.	Low	High
Anachemia C2					
Color Ticket	GB			c	
Color Tubes	HD			d	d
Anachemia CM256A1					
Multifunction Card	GB				
	HD				
Draeger Civil Defense Kit	GB		e		
	HD				
MSA Single CWA Kit	GB		f		
	HD				
Nextteq Civil Defense Kit					
Color Tubes	GB				
	HD				
Proengin AP2C	GB				
	HD				
RAE MultiRAE Plus	GB				
	HD				
S. S. HazMat Smart Strip	GB				
Smiths Detection APD2000	GB				
	HD		g		h
Truetch M18A3 Ticket	GB				

DETECTION LIMITS

- Instruments designed for CWA usually have only a bar graph or series of light bars to indicate low, medium, high hazards.
- Detection limits refer to a concentration that will cause some change in the display.
- Detection limits given here are combination of ECBC and NIJ.

DISPLAY EXAMPLE

EXPOSURE LIMITS

CHEMICAL	8 hour TWA (ppm)	IDLH (ppm)
GA/GB (Tabun/Sarin)	0.000005	0.02
HD	0.00006	0.1
VX	0.00000009	0.0003

SOURCE: CDC 2003 & 2004

TYPES OF DETECTORS

- Detectors used in CWA instruments
  - Ion mobility spectrometer
  - Flame photometric detector
  - Surface acoustic wave sensor

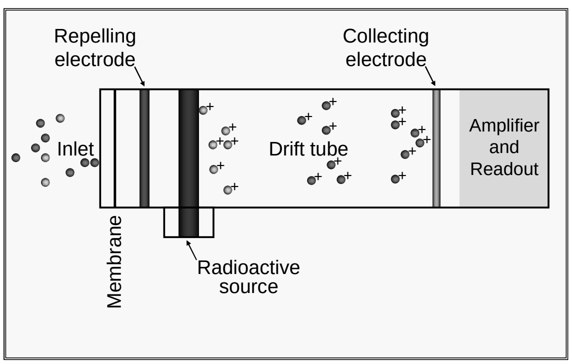
TYPES OF DETECTORS

- Typical industrial detectors
  - Infrared spectrometer
  - Colorimetric indicator
  - Photoionization detector
  - Flame ionization detector
  - Gas chromatograph

ION MOBILITY SPECTROMETER (IMS)

- Sample air is drawn through a heated membrane into the cell assembly
- Molecules are ionized by a radioactive source
- Resulting ions are swept down a drift tube towards a collector electrode
- The ions become separated by their mass and mobility

IMS



IMS EXAMPLES

- APD2000
- ChemPro 100
- Draeger IMS
- ChemRAE
- Sabre FR
- LCD-FR


APD2000


LCD-FR

APD2000

APD2000 DETECTION LIMITS

- GA/GB: 0.004 ppm
- GD/VX: 0.015 ppm
- H, HD: 0.033 ppm
- Lewisite: 0.2 ppm
- Also detects pepper spray and Mace®

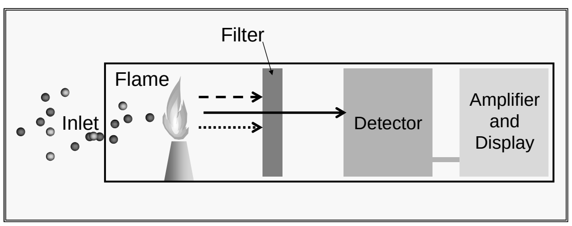
IMS CONSIDERATIONS

- False positives include wintergreen, alcohols, diesel fuel, cleaners
- May require sample time for readout (15 – 200 seconds)
- May require purging of chamber between readings
- Radioactive source

FLAME PHOTOMETRIC DETECTOR (FPD)

- Air is drawn into and heated to high temperature in a hydrogen burner
- As chemicals burn, they emit certain wavelengths of light
- Detector looks for specific wavelengths of light from phosphorus and sulfur atoms found in nerve and mustard agents

FPD



FPD EXAMPLES

- UC AP4C/AP2C
- Agilent GC-FPD
- MINICAMS GC-FPD

AP2C

FPD CONSIDERATIONS

- False positives include chemicals containing sulfur and phosphorus
- Hydrogen fuel needed
- Detection limits
  - GA, GB: 0.004 ppm
  - GD, VX: 0.001 ppm
  - HD: 0.142 ppm

SURFACE ACOUSTIC WAVE (SAW) SENSOR

- Piezoelectric crystals detect the mass of chemical vapors absorbed into chemically selective coatings on the sensor's surface
- Absorption causes a change in the resonant frequency of the sensor
- An internal microcomputer measures these changes and determines the presence and concentration of chemical agents

SURFACE ACOUSTIC WAVE (SAW) SENSOR

SAW coatings have unique properties that allow a reversible absorption of chemical vapors.

SAW EXAMPLES

- SAW MiniCAD – 2 SAW sensors
- HAZMATCAD/HAZMATCAD Plus – 3 SAW sensors + EC
- Multiple sensors
  - Allow identification of different chemical agents
  - Reduce interferences

SAW MINICAD

MINICAD DETECTION LIMITS

- GA: 0.74 ppm
- GB: 0.07 ppm
- GD: 0.02 ppm
- VX: 0.01 ppm
- H, HD: 0.35 ppm

COMBINATION UNITS

- S-CAD
  - IMS
  - SAW
  - Toxic sensors
- HGVI
  - IMS (x2)
  - PID
  - Toxic sensors
  - Gamma radiation

LIGHT ABSORPTION DETECTORS

- Detection is based on the absorption of certain wavelengths (infrared or ultraviolet) by chemical bonds (such as P=O)
  - May be a closed system – air is drawn inside the instrument
  - May be an open system – the beam is aimed at the atmosphere

EXAMPLES

- Closed system
  - SaphIRe (IR)
  - UV Hound (UV)
- Open system
  - M21 RSCAAL
  - RAPID I
  - ASPECT

M21 RSCAAL

DETECTION LIMITS

- For open systems, depends on path length of beam
- SaphIRe (ECBC)
  - GA: 0.2 ppm
  - GB: 0.1 ppm
  - HD: 0.4 ppm
- UV Hound (manufacturer)
  - GB: 0.01 ppm
  - HD: 0.03 ppm

IR CONSIDERATIONS

- Open systems allow stand-off detection
- Affected by environmental conditions
- Interferences depend on the wavelength used to detect particular bond
  - e.g., Halon – fluorine atom bond
  - e.g., organophosphate pesticides – P=O bond
- Multiple wavelength scans may allow better identification

COLORIMETRIC INDICATORS

- Detection of a chemical is based on a color change reaction
- The chemical in the air reacts with a reagent in a tube or in an indicator patch
- Non-military models are based on detecting industrial chemicals with similar specific properties (pesticides, arsenic)

COLORIMETRIC INDICATORS

- M256A1 detector kit
- Detector tubes
  - Draeger
  - MSA
  - Nextteq
- Chameleon

M256A1 DETECTOR KIT

M-256A1 DETECTOR KIT

- Nerve – G & V – *star test spot*
  - GB: 0.0008 ppm
  - VX: 0.002 ppm
- Blister – H, HD – *square test spot*
  - 0.31 ppm
- Blood – HCN, CK – *round test spot*
  - HCN: 7.13 ppm
- Lewisite – *detecting tablet*
  - 1 ppm

DRAGER CIVIL DEFENSE SET CDS I

Agent	Tube	Sensitivity
Hydrocyanic Acid	Hydrocyanic acid	1 ppm
Phosgene	Phosgene	0.2 ppm
Lewisite	Organic Arsenic Compounds/Arsine	3 mg/m^3
N-Mustard	Organic Basic Nitrogen Compounds	1 mg/m^3
S-Mustard	Thioether	1 mg/m^3

SOURCE: Drager Fact Sheet

DRAGER CIVIL DEFENSE SET CDS V

Agent	Tube	Sensitivity
Nerve Agents	Phosphoric Acid Esters	0.025 ppm
Phosgene	Phosgene	0.2 ppm
Cyanogen Chloride	Cyanogen Chloride	0.25 ppm
Chlorine	Chlorine	0.2 ppm
S-Mustard	Thioether	1 mg/m^3

SOURCE: Drager Fact Sheet

PHOTOIONIZATION DETECTORS (PID)

- Ultraviolet light used to ionize molecules
- Lamp energy must equal or exceed IP of chemical to be able to detect it
- Interferences
  - Any other ionized molecule
  - Humidity
- Lamp clouding

PID DETECTION LIMITS

- GA: 0.5 ppm
- GB: 11 ppm
  0.5 ppm (11.7eV)
- GD: 0.5 ppm
- HD: 0.26 ppm
- Phosgene: 2 ppm (11.7eV)
- Lewisite: 0.5 ppm

10.6 eV lamp unless noted otherwise

FID CONSIDERATIONS

- Hydrogen flame ionizes molecules
- Interferences – any other organic vapor
- Detection limits
  - GA/GB: 0.6 ppm
  - HD: >4.27 ppm
- Detector deterioration

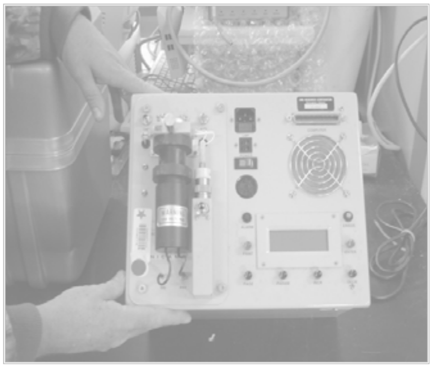
GAS CHROMATOGRAPHY (GC)

- Mixtures are separated by a column and sent to a detector
- Combination of retention time and selectivity of the detector is used for identification

GCs

Example	Detector
MINICAMS	Flame photometric
Hapsite	Mass spectrometer
Agilent	Flame photometric and mass selective
Scentoscreen	Argon ionization

MINICAMS



MINICAMS DETECTION LIMITS

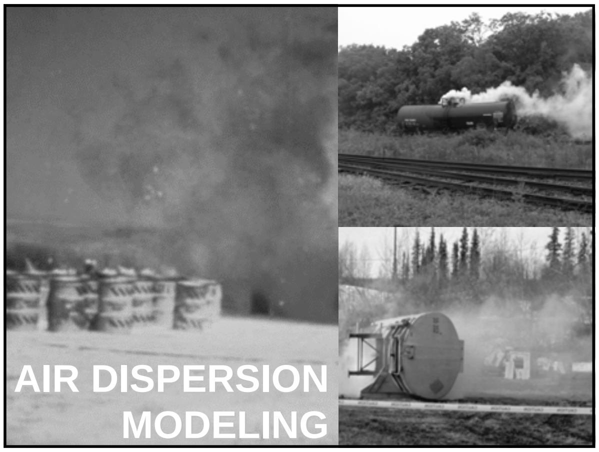
- GA: 0.00013 ppm
- GB: 0.00017 ppm
- H, HD, HN: 0.0006 ppm
- VX: 0.00001 ppm

GC CONSIDERATIONS

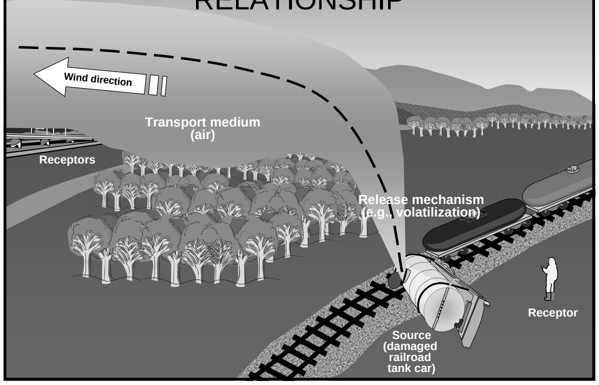
- Long response time
  - Column elution
  - Pre-concentration sampling
- Not necessarily portable
- Interference problems depend on elution times and detector selectivity
- Very good detection limits

SUMMARY

- Identified sources of information
- Discussed the principles of operation for different CWA detectors
- Showed examples of instruments
- Discussed considerations for using the instruments



SOURCE-RECEPTOR RELATIONSHIP



DISPERSION MODELING APPLICATIONS

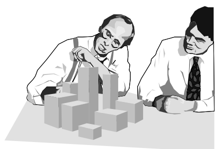
The two major dispersion modeling applications for are:

- Estimating average concentrations at receptors of interest based on the source(s) of concern
- Designing an air monitoring program

Source: U.S. EPA 1989

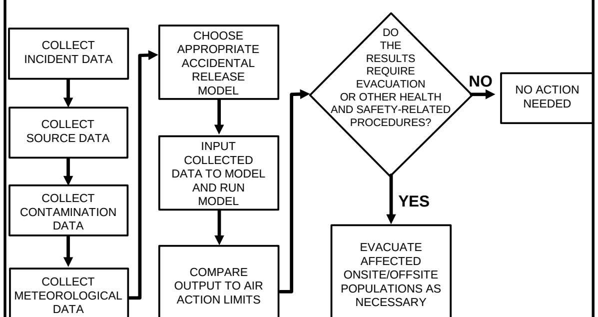
DISPERSION MODEL CLASSES

PHYSICAL MODELS



MATHEMATICAL MODELS

DISPERSION MODELING DURING AN EMERGENCY

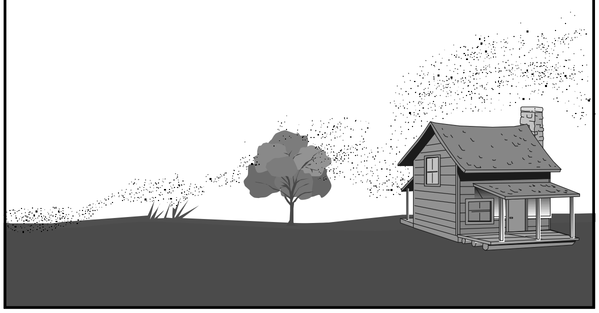


INCIDENT DATA

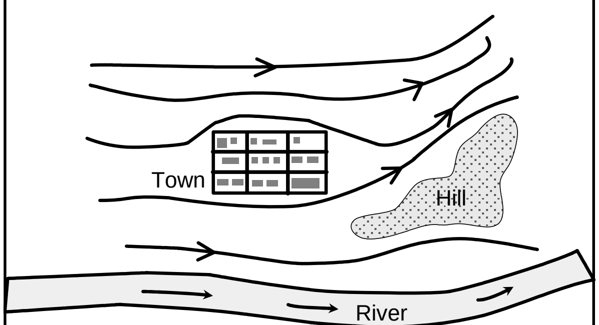
- General characteristics of the incident
- Characteristics of the surrounding environment

Source: U.S. EPA 1995

GROUND ROUGHNESS

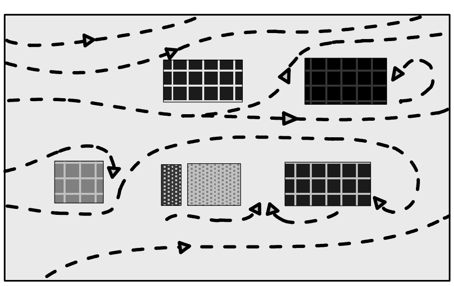


TERRAIN STEERING EFFECTS



Adapted from: EPA 2007

SMALL-SCALE VARIATIONS IN WIND DIRECTION



Source: U.S. EPA 2007

SOURCE DATA

- Types of sources
- Duration and frequency of releases
- Emission rate estimates

Source: U.S. EPA 1995

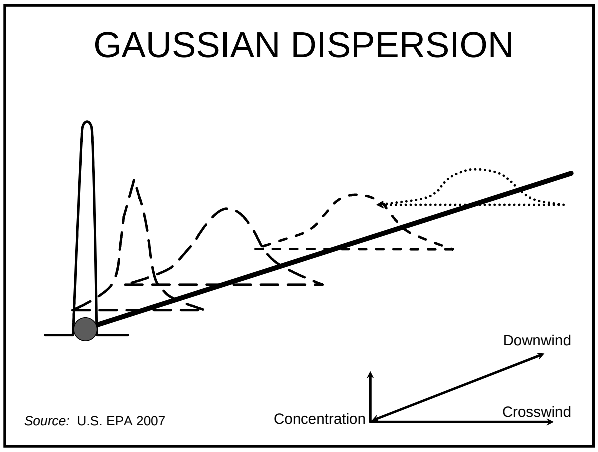
CONTAMINATION DATA

- Physical, chemical, and toxicological properties of pollutants to be modeled
- Concentration averaging times associated with pollutants to be modeled

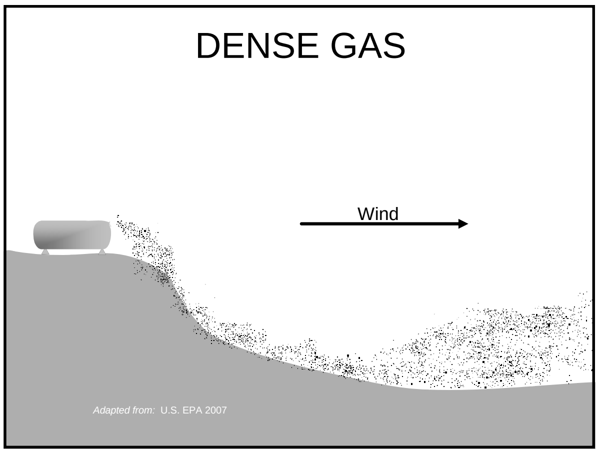
Source: U.S. EPA 1995

GAS DENSITY EFFECTS ON DISPERSION

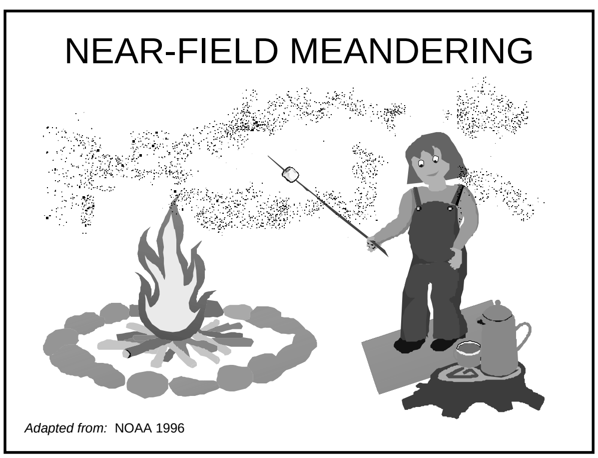
- Gaussian dispersion
- Dense gas release
- Near-field meandering



Source: U.S. EPA 2007



Adapted from: U.S. EPA 2007



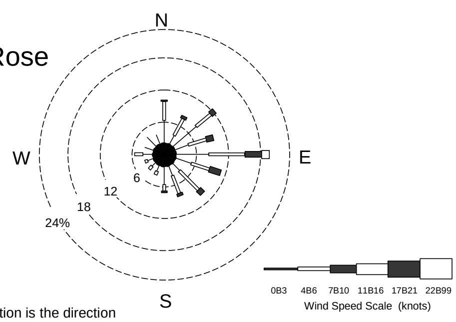
Adapted from: NOAA 1996

METEOROLOGICAL DATA

- Wind direction and speed
- Stability
- Inversions
- Temperature
- Humidity
- Atmospheric pressure

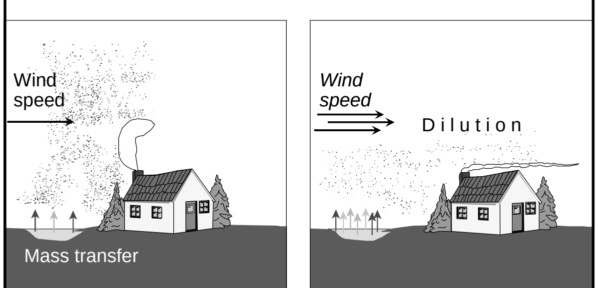
EFFECTS OF WIND SPEED AND DIRECTION

Wind Rose

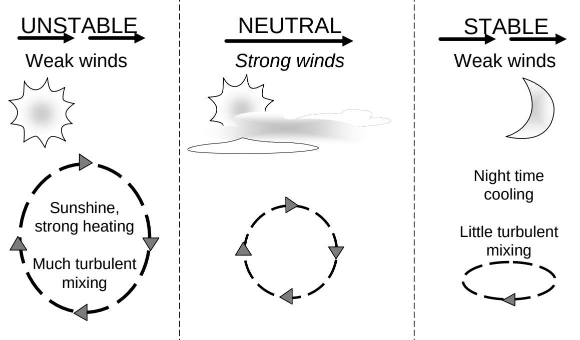


Note: Wind direction is the direction from which the wind is blowing

WIND SPEED EFFECTS



STABILITY CLASS



Adapted from: U.S. EPA 1999

KEY TO STABILITY CATEGORIES

Wind Speed (meters per second)	Day Incoming Solar Radiation			Night Cloud Cover	
	Strong	Moderate	Slight	>50%	<50%
<2	A	A-B	B	E	F
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

Stability is D for completely overcast conditions during day or night

Source: U.S. EPA 1999

EFFECTS OF WIND SPEED

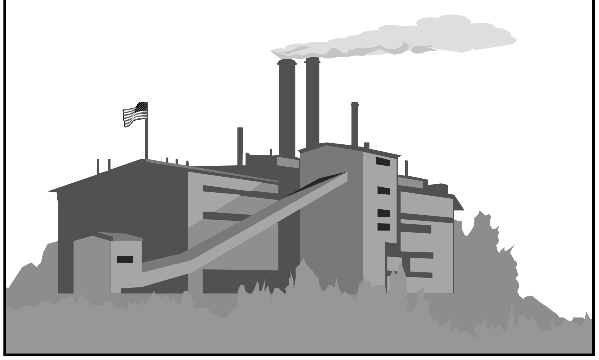
	Daytime	Nighttime
WEAK WINDS	↓ STABILITY	↑ STABILITY
STRONG WINDS	↑ STABILITY	↓ STABILITY

INVERSION

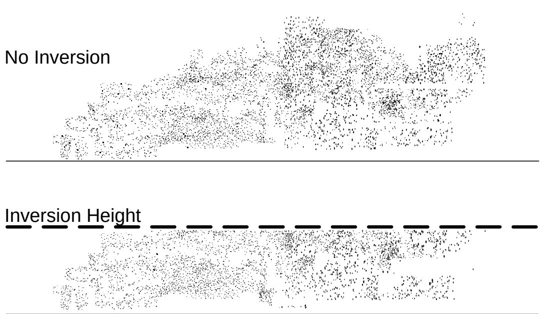
- An atmospheric condition in which an unstable layer of air near the ground lies beneath a very stable layer of air above*
- Inversions can affect dispersion in two ways

**Source:* U.S. EPA 1999

INVERSION AND WIND DIRECTION



INVERSIONS AND TRAPPING



Source: NOAA 1996

ADDITIONAL METEOROLOGICAL DATA

- Ambient temperature
- Relative humidity
- Atmospheric pressure

Source: U.S. EPA 1995

OFF-SITE EXPOSURE MODEL TYPES

- Contingency
- Accidental release
- Short-term site assessment
- Long-term site assessment

CONTINGENCY MODELS

- Provide worst-case results
- Conducted prior to releases
- Use historical meteorological data
- Examples: ALOHA®, HPAC and RMP*Comp

ACCIDENTAL RELEASE MODELS

- Provide worst-case results
- Results used to determine evacuation or shelter-in-place options
- Typically generate own source term
- Examples: ALOHA®, HPAC

SHORT-TERM SITE ASSESSMENT MODELS

- Modeling concentrations averaged for a year or less
- Used in risk assessments
- Detailed results for several receptors
- Examples: AERMOD, CALPUFF, CTMDPLUS

LONG-TERM SITE ASSESSMENT MODELS

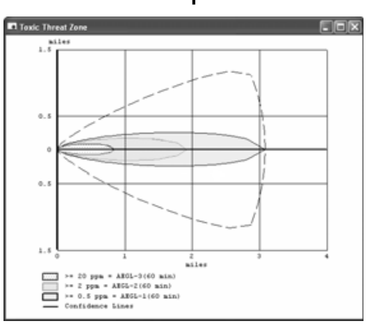
- Modeling concentrations averaged for a year or more
- Long-term meteorological data needed
- Multiple receptors
- Examples: AERMOD, CALPUFF, CTMDPLUS

MODEL OUTPUT
Concentration and Distance

Downwind Distance (feet)	Concentration (ppm)
100	19,400
1120	226
2140	74
3160	39
5200	17
7240	10

MODEL OUTPUT
Distance to Toxic Endpoint

MODEL OUTPUT
Footprint



Source: U.S. EPA 2007

MODEL OUTPUT
Plume Hazard Area

Source: NARAC 2004

NARAC

- National Atmospheric Release Advisory Center
- Located at Lawrence Livermore National Laboratory (LLNL)
- Internet accessible
- Need account
- Has been used by EPA OSCs for some time
- https://narac.llnl.gov

NARAC

Support four phases of emergency response:

- Early-Time: First few hours
  - Provide immediate guidance for dose-avoidance or protective actions.
  - Provide guidance for deployment of initial field measurement resources.
- Mid-Time: First 2 days
  - Provide predictions to help screen and evaluate field measurements.
  - Develop quantitative estimate of total release using model simulations and field measurements.

Source: https://narac.llnl.gov

NARAC

Support four phases of emergency response:

- Late-Time: After first 2 days
  - Provide reconciliation assistance using model simulations refined using field measurements
  - Develop area-contamination & population dose estimates
- Post-accident analyses:
  - Using more detailed information collected during or after an accident, NARAC can perform more precise analyses in a non time-intensive mode after the event. If any measurements of the release were taken, NARAC can recreate a source term to match those values

Source: https://narac.llnl.gov

IMAAC

- Interagency Modeling and Atmospheric Assessment Center of the Department of Homeland Security
- Under the National Response Plan (NRP), it is to be used for all Incidents of National Significance (INS)
- Web and Internet based software
- Currently using NARAC

IMAAC

- Radiological, chemical and biological properties
- Dose factors, dose limits, and protective action guides
- Uses US Census population density data to estimate impacts
- Specialized residential building leakiness program

WEBSITES
AIR DISPERSION MODELS

www.epa.gov/scram001
- Support center for regulatory air models
- EPA models

www.epa.gov/emergencies/tools.htm
- EPA databases and software
- CAMEO/ALOHA

AIR DISPERSION MODELING CONCLUSION

- Models are predictive tools
- Choose appropriate model(s)
- Need adequate input data
- Experienced modeler is recommended

Air Dispersion Computer Model Demonstration

Student Performance Objectives

Upon completion of this unit, students will be able to:

1. List the five effects the ALOHA® model does *not* incorporate, as stated in the ALOHA® limitations screen.
2. Using the ALOHA® model and given Site Data (location, date, and time), a chemical, atmospheric conditions, type of source, type of release, and a level of concern, display a Toxic Threat Zone.
3. Given a Toxic Threat Zone and a location within the Zone, display a Concentration at Point for the location.

SOURCE: ALOHA® User's Manual, Chapter 3, Example 1, pages 49-65
U.S. Environmental Protection Agency
Office of Emergency Management
Washington, D.C.

National Oceanic and Atmospheric Administration
Office of Response and Restoration
Emergency Response Division
Seattle, Washington

Revised February 2007

3

Examples

This chapter contains three step-by-step ALOHA example scenarios. You can complete the first two scenarios using only ALOHA. To complete the third scenario, you'll also need the electronic mapping application, MARPLOT, as well as the sample map of Prince William County supplied with MARPLOT.

Example 1: A Tank Source (Puddle and Pool Fire)

In a small industrial park outside Baton Rouge, Louisiana, a 500-gallon, 4-foot-diameter, vertical tank contains liquid benzene. On August 20, 2006, at 10:30 p.m. local time, a security guard discovers that liquid is leaking out of the tank through a 6-inch circular hole located 10 inches above the bottom of the tank. He also sees that the liquid is flowing onto a paved area in the industrial park. The guard thinks that the tank has just been filled that evening.

The temperature on scene is 80°F, with the wind from the southwest at 7 miles per hour (as measured at a height of 10 meters by a fixed meteorological tower at the site). The sky is more than half covered by clouds and the humidity is about 75 percent. A thunderstorm is approaching from the southwest. There is no low-level inversion. There are very few buildings in the industrial park and a large grassy field is located to the northeast of the industrial park.

The Local Emergency Planning Committee has requested that on-scene responders use ERPG-2 concentrations to define the toxic endpoints in their analysis of benzene hazards.

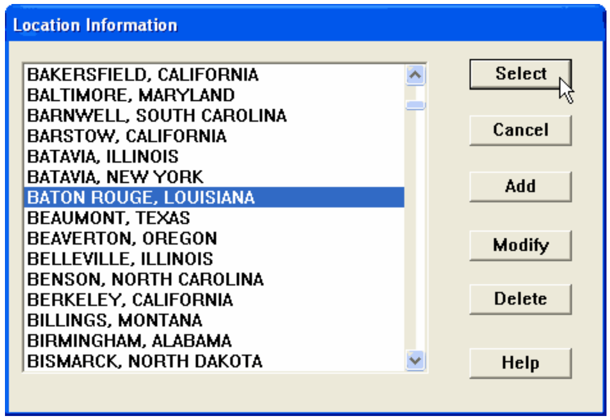
In this example scenario, you'll determine:

1. Distance to the ERPG-2 level if the puddle evaporates and forms a toxic vapor cloud; and
2. Thermal radiation threat if the puddle is ignited by a lightning strike and forms a pool fire.

Choosing a location and a chemical

1. Start ALOHA. (In Windows, click the **Start** button, point to **Programs**, then choose the **ALOHA** item. On a Macintosh, double-click the **ALOHA** program icon located in the **ALOHA folder**.)
2. Read the list of ALOHA's limitations (click **Help** to see more details), then click **OK**.
3. Select **Location** from the **SiteData** menu. A Location Information dialog box appears with a list of the names of cities included in ALOHA's location library.

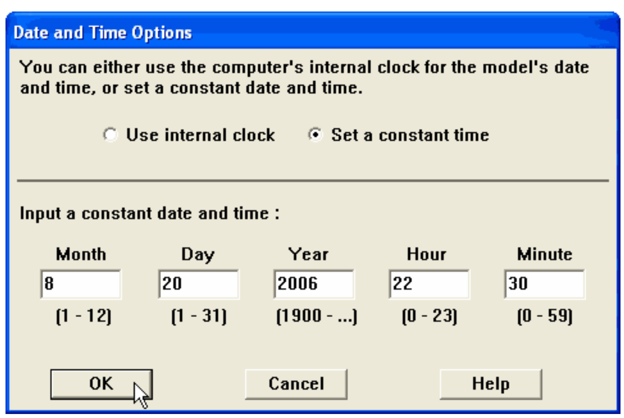
4. The industrial park is located outside Baton Rouge, Louisiana. Type the characters "ba" to quickly move to the section of the list containing names beginning with "ba." Scroll down a little farther until you see BATON ROUGE, LOUISIANA. Click on this name to highlight it, then click **Select**.



In this example, you will not modify the default building type settings because you will not assess indoor concentration at specific locations.

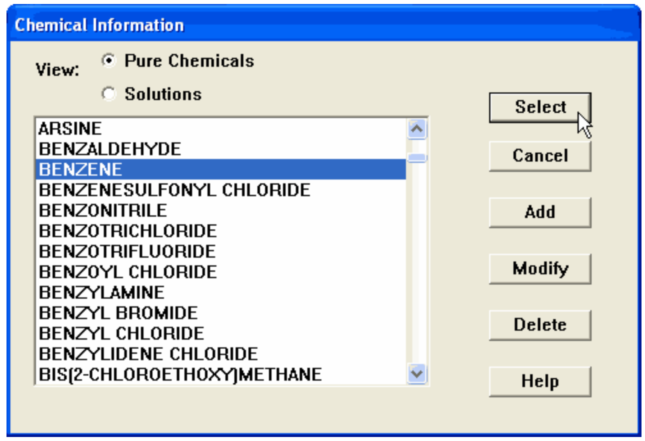
5. Select **Date & Time** from the **SiteData** menu. A Date and Time Options dialog box appears.

6. The release occurs at 10:30 p.m. on August 20, 2006. Select the **Set a constant time** option. Enter the month, day, year, hour, and minute for this scenario (press Tab to move from one box to the next). ALOHA requires you to convert the time of day into 24-hour time (click Help to learn how to convert time values). Click **OK**.



7. To choose the chemical that is being released—benzene—select **Chemical** from the **SetUp** menu. A Chemical Information dialog box appears with a list of the chemicals in ALOHA's chemical library.

8. Select **Pure Chemicals** at the top of the window (this should be the default). Find BENZENE in the list (type the character "b" to locate benzene more rapidly in the list), click on this name, then click **Select**.



Entering weather information

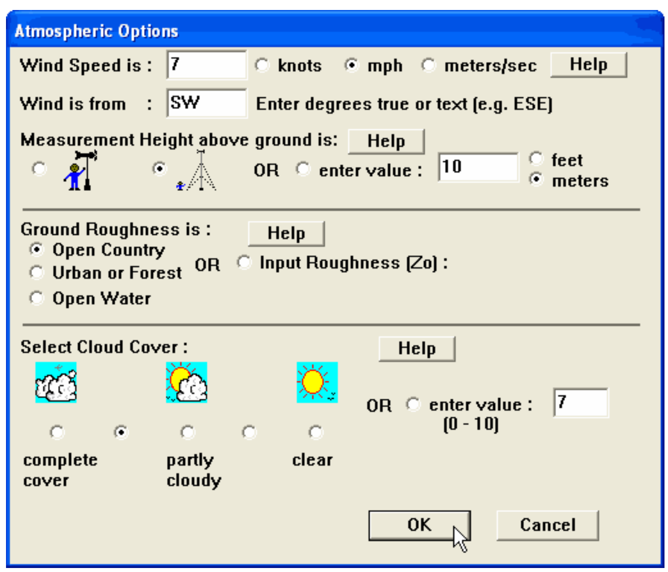
Now that you've selected the location, time, and chemical, you must provide information about weather conditions and ground roughness.

1. In the **SetUp** menu, point to **Atmospheric**, then select **User Input**. The first Atmospheric Options dialog box appears.

2. The wind is travelling from the southwest at a speed of 7 miles per hour. Type "7" in the wind speed box, then select **mph**. Type "SW" in the wind direction box.

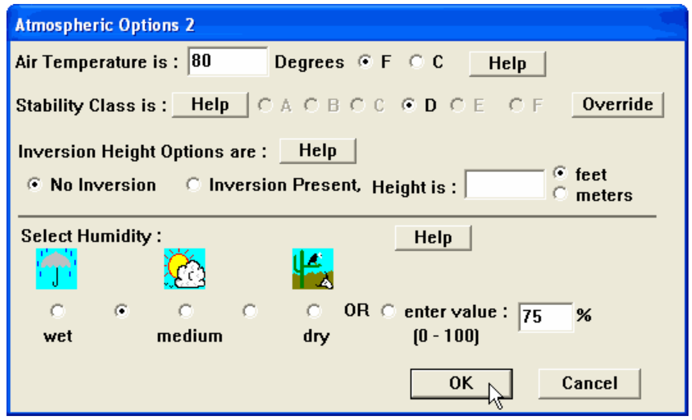
3. The wind conditions are measured at a height of 10 meters. Select the **tower icon** in the Measurement Height section. Notice that ALOHA has filled in a value of 10 meters.

4. There are very few buildings in the industrial park and a large grassy field is located to the northeast (the area where the wind would blow the toxic vapor cloud). Select the **Open Country** ground roughness option.



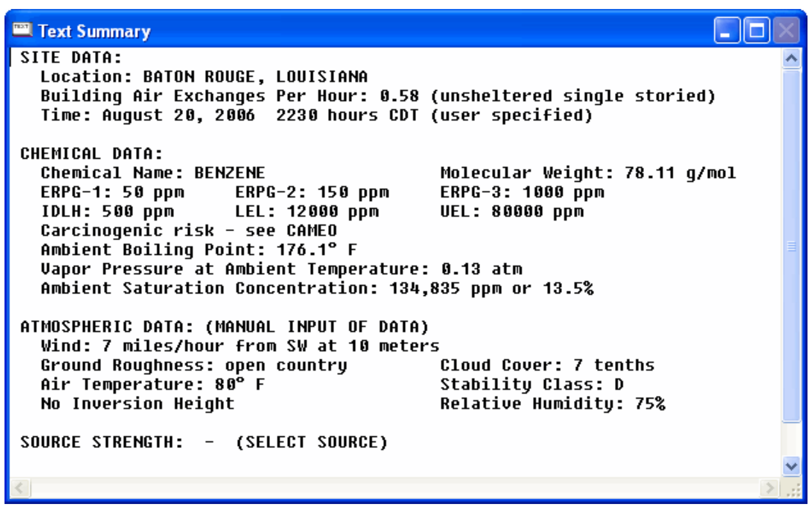
5. The sky is more than half covered by clouds. Under Select Cloud Cover, choose the second option from the left (the option between the complete cover and partly cloudy options). Notice that ALOHA has filled in a value of 7. Click **OK**. The second Atmospheric Options dialog box appears.

6. The air temperature is 80°F. Type "80" in the air temperature box, then select **F**.
7. ALOHA uses the wind speed, cloud cover, and date and time information that you've entered to automatically select atmospheric Stability Class D, representing conditions of neutral atmospheric stability.
8. There is no low-level inversion. Check to be sure that **No Inversion** is selected.



9. The relative humidity is about 75 percent. Choose the second option from the left (the option between the wet and medium options). Notice that ALOHA has filled in a value of 75 percent. Click **OK**.

The information that you have entered into ALOHA appears in the Text Summary. Ignore ALOHA's estimate of building exchange rate, since you are not considering infiltration into buildings.



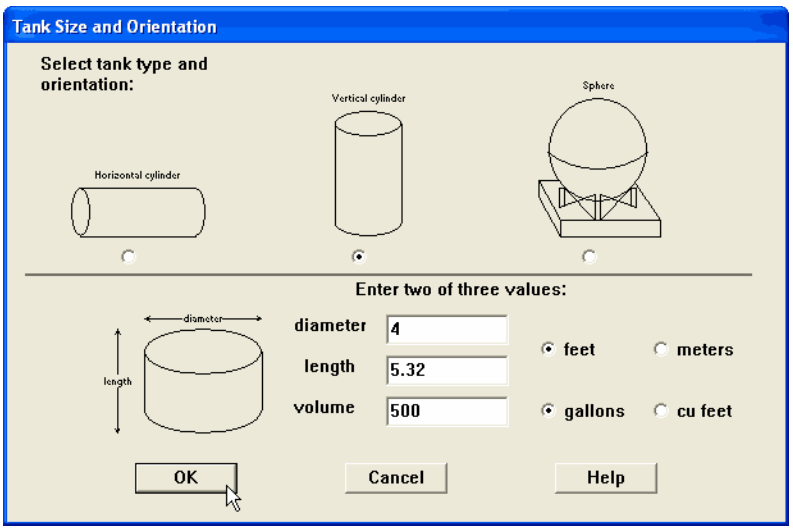
Text Summary

```
SITE DATA:
  Location: BATON ROUGE, LOUISIANA
  Building Air Exchanges Per Hour: 0.58 (unsheltered single storied)
  Time: August 20, 2006  2230 hours CDT (user specified)

CHEMICAL DATA:
  Chemical Name: BENZENE                  Molecular Weight: 78.11 g/mol
  ERPG-1: 50 ppm      ERPG-2: 150 ppm     ERPG-3: 1000 ppm
  IDLH: 500 ppm       LEL: 12000 ppm      UEL: 80000 ppm
  Carcinogenic risk - see CAMEO
  Ambient Boiling Point: 176.1° F
  Vapor Pressure at Ambient Temperature: 0.13 atm
  Ambient Saturation Concentration: 134,835 ppm or 13.5%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 7 miles/hour from SW at 10 meters
  Ground Roughness: open country          Cloud Cover: 7 tenths
  Air Temperature: 80° F                  Stability Class: D
  No Inversion Height                     Relative Humidity: 75%

SOURCE STRENGTH:  -  (SELECT SOURCE)
```

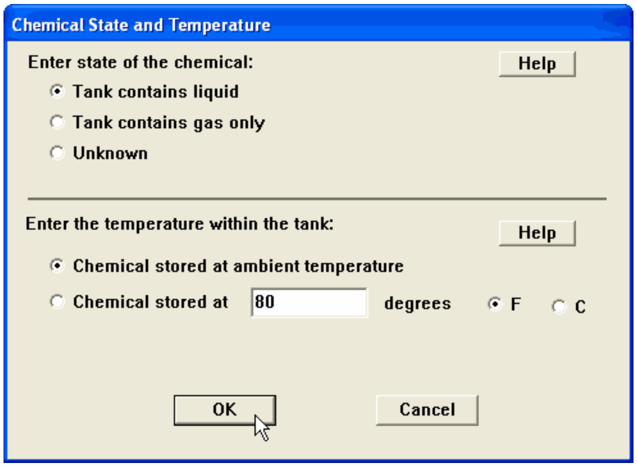
Describing the release

Now you're ready to enter information about the release itself—that is, to "set the source"—for this release.

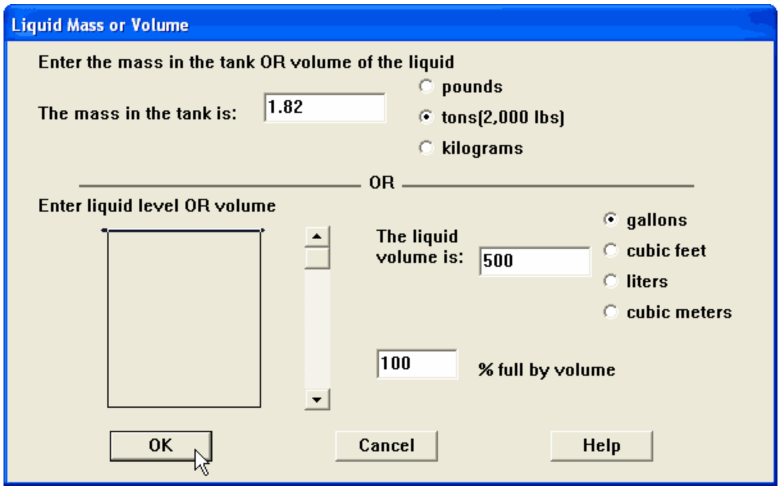
1. The benzene is leaking from a tank. In the **SetUp** menu, point to **Source**, then select **Tank**. A Tank Size and Orientation dialog box appears.
2. The benzene is stored in a 500-gallon, 4-foot-diameter, vertical tank. Select **Vertical cylinder**. Type "500" in the volume box, then select **gallons**. Type "4" in the diameter box, then select **feet**. Notice that ALOHA automatically calculates the tank length. Click **OK**. A Chemical State and Temperature dialog box appears.



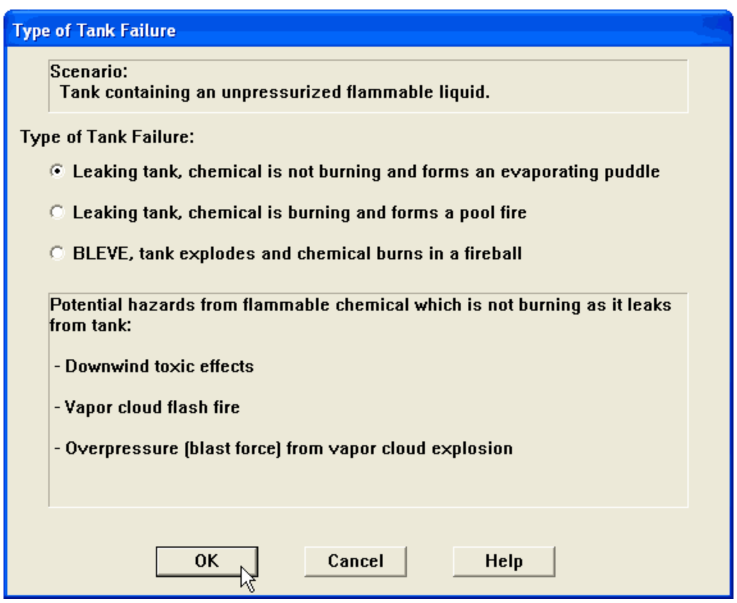
3. The benzene is stored in the tank as a liquid (notice in the Text Summary that it has a boiling point of 176°F, well above the ambient temperature). Select the **Tank contains liquid** option. Check to be sure that **Chemical stored at ambient temperature** is selected. Click **OK**. A Liquid Mass or Volume dialog box appears.



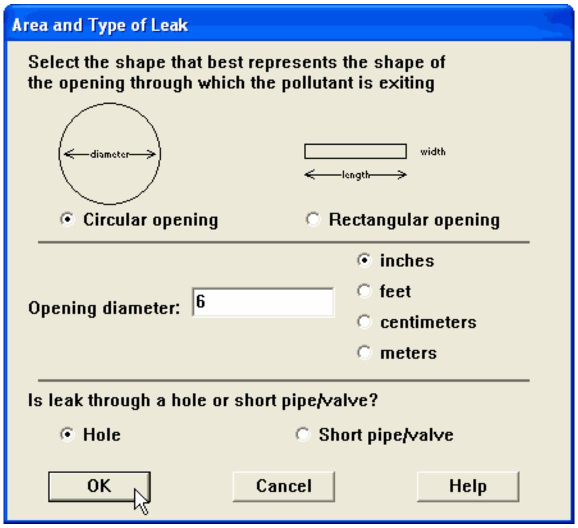
4. The security guard thinks the 500-gallon tank was filled that evening, so the most conservative estimate you can make is that the tank is 100 percent full. Either (1) type "100" in the % full by volume box, (2) type "500" in the liquid volume box, then click **gallons**, or (3) scroll the liquid level bar to the top of the tank diagram. Notice that ALOHA fills in the other values. Click **OK**. A Type of Tank Failure dialog box appears.



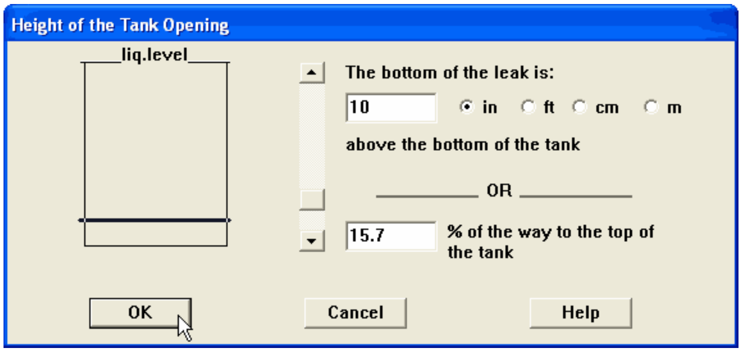
5. Initially, the benzene is leaking from a hole in the tank, but it is not burning. Choose the **Leaking tank, chemical is not burning and forms an evaporating puddle** option. Click **OK**. An Area and Type of Leak dialog box appears.



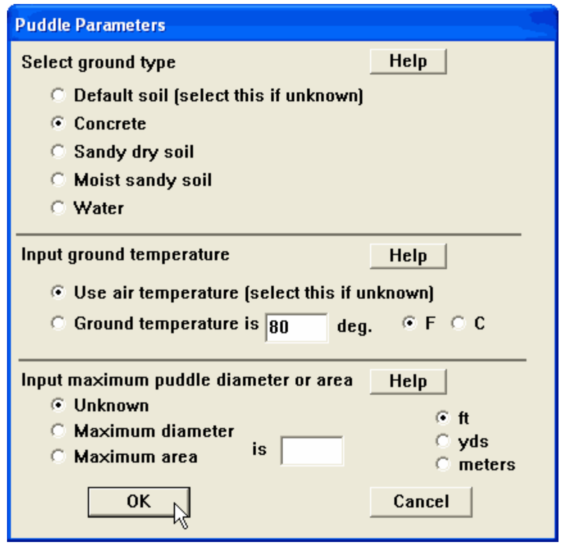
6. The benzene is leaking from a 6-inch circular hole. Check to be sure that **Circular opening** is selected. Type "6" in the opening diameter box and select **inches**. Choose the **Hole** option. Click **OK**. A Height of the Tank Opening dialog box appears.



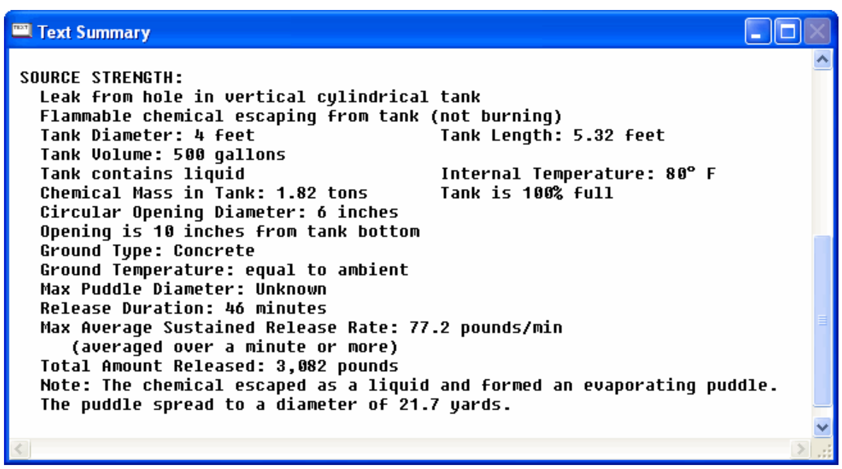
7. The hole is 10 inches above the bottom of the tank. Type"10" in the bottom of the leak box and select **in**. Notice that ALOHA fills in the other values. Click **OK**. A Puddle Parameters dialog box appears.



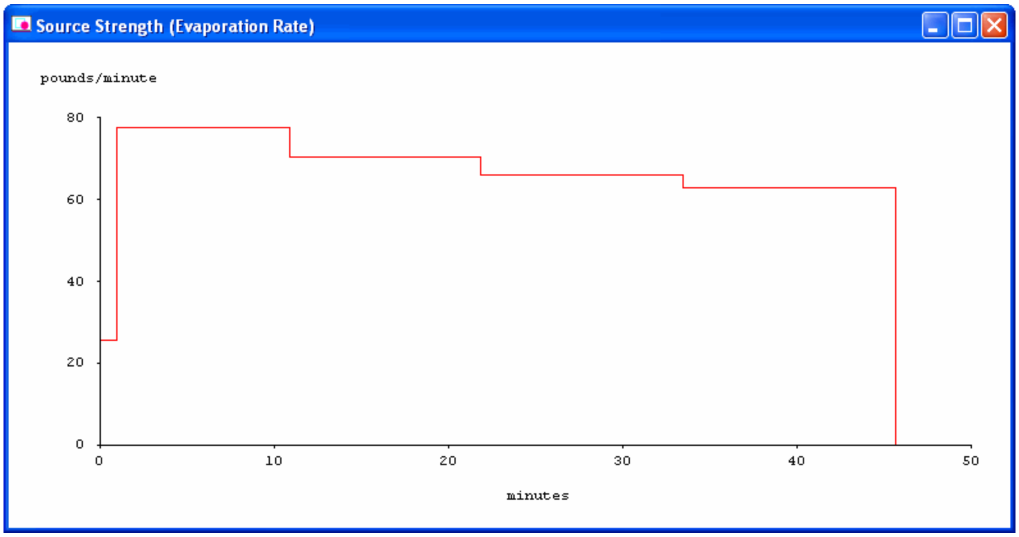
8. The liquid benzene is flowing onto a paved area in the industrial park. Select the **Concrete** ground type. Since you have no information about the ground temperature, select **Use air temperature (select this if unknown)**. Because the product is flowing onto a paved area, it is probably not contained by a dike, so it will continue spreading outward until it reaches a minimum thickness. Under the "Input maximum puddle diameter or area" heading, click **Unknown**. ALOHA will calculate the area for you based on the release information you provided (up to a maximum diameter of 200 meters). Click **OK**.



The source strength information that you have entered, and the results of ALOHA's source strength calculations, appear in the Text Summary. ALOHA estimates that the release of vapor into the atmosphere lasts for about 46 minutes, and that the maximum amount of vapor released at any one time is 77.2 pounds per minute (this is the Maximum Average Sustained Release Rate). ALOHA estimates that the puddle reached a maximum diameter of 21.7 yards.



9. Choose **Source Strength** from the **Display** menu to see the source strength graph for this scenario. The graph shows the predicted averaged release rate during the hour after the release begins.



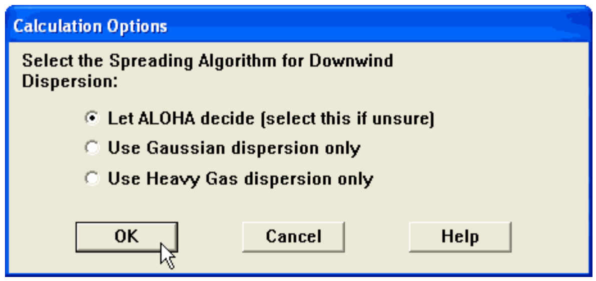
Whenever you run ALOHA, ask yourself: Is ALOHA accurately representing what is actually occurring in this scenario? In this case, liquid benzene leaks from a tank to form a puddle; ALOHA expects that because the puddle is undiked, it spreads out to cover a large area and evaporates at a high rate for a relatively short period of time. What if the puddle were constrained by small depressions in the ground? The puddle would not spread out as far because the liquid flowing away from the tank would fill up the depressions in the ground. The puddle would then be smaller in area and deeper. It would evaporate at a slower rate and it would take longer to completely evaporate.

Because ALOHA assumes that the puddle is on a perfectly flat surface and would spread out until it was very thin, ALOHA may overestimate the real puddle size and evaporation rate. At a real accident scene, check for terrain features that would constrain the puddle from spreading; use this information to estimate the maximum puddle area.

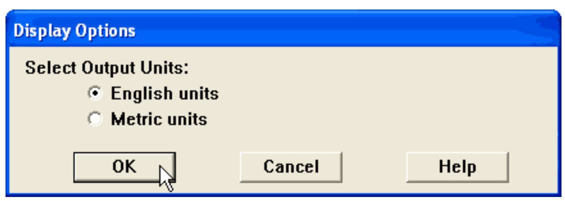
Checking the Calculation and Display Options Settings

You don't know if the toxic gas is a heavy gas or not, so you'll want ALOHA to use information about the properties of the chemical and the amount of chemical released to choose whether to make Gaussian or heavy gas dispersion computations. Check to be sure that ALOHA is set to this default.

1. Select **Calculation Options** from the **SetUp** menu. A Calculation Options dialog box appears.
2. Check to be sure that **Let ALOHA decide (select this if unsure)** is selected. Click **OK**.



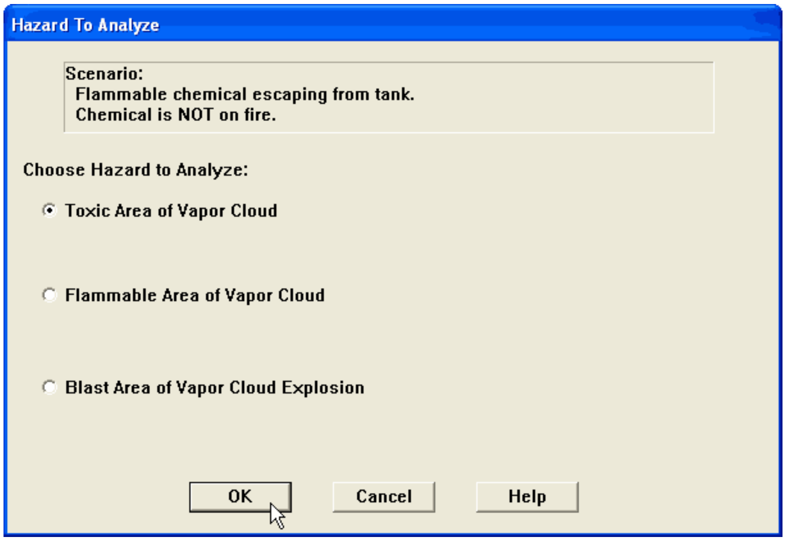
3. Select **Display Options** from the **Display** menu. A Display Options dialog box appears. Select **English units** and ALOHA's computation results will be displayed in those units. (When running ALOHA, you can choose either type of units, but for this example English units have been selected.) Click **OK**.



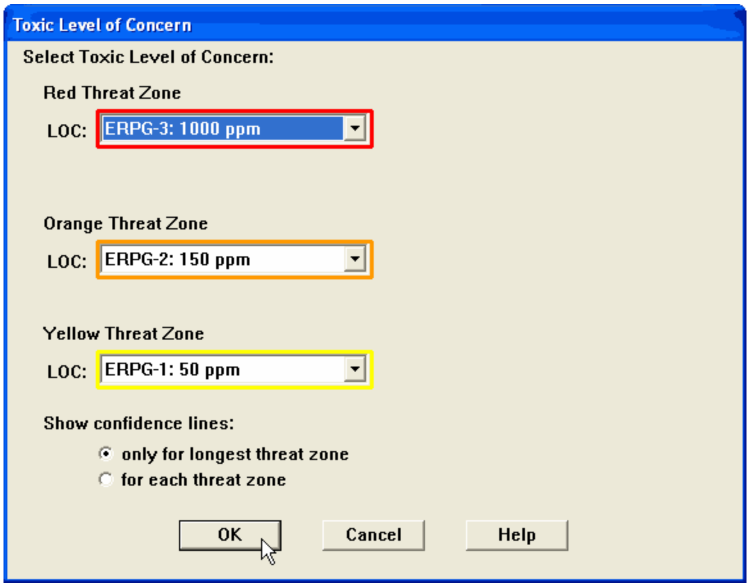
Choosing LOCs and creating a threat zone plot

1. Choose **Threat Zone** from the **Display** menu. A Hazard To Analyze dialog box appears.

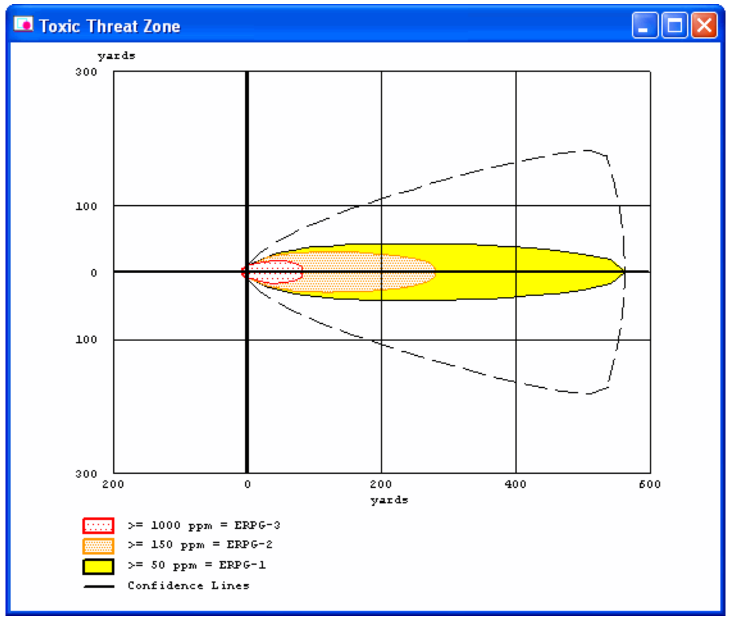
2. As the puddle evaporates, a vapor cloud forms. ALOHA can help you model three possible hazardous scenarios for the flammable vapor cloud: toxic area, flammable area, or blast area. For this example, you want to display the toxic area on a threat zone plot. Select the **Toxic Area of Vapor Cloud** option. Click **OK**. A Toxic Level of Concern dialog box appears.



3. ALOHA uses ERPGs (Emergency Response Planning Guidelines) as the default LOCs for benzene, so you'll keep the default LOCs and check that **Show confidence lines only for the longest threat zone** has been selected. Click **OK**. ALOHA will display a threat zone plot for this release.



You'll see ALOHA's threat zone plot for this scenario, showing three toxic threat zones. You want to know the downwind distance to the ERPG-2 level specified by the Local Emergency Planning Committee. ALOHA estimates that the orange threat zone—the ERPG-2 level—will extend 281 yards downwind (the exact value for this *threat distance* is displayed in the Text Summary). Within this zone, ground-level benzene concentrations might exceed the ERPG-2 level. At concentrations above the ERPG-2 level, people could experience serious health effects or find their ability to escape to be impaired (if they are exposed for about an hour).



Check the Text Summary for this release.

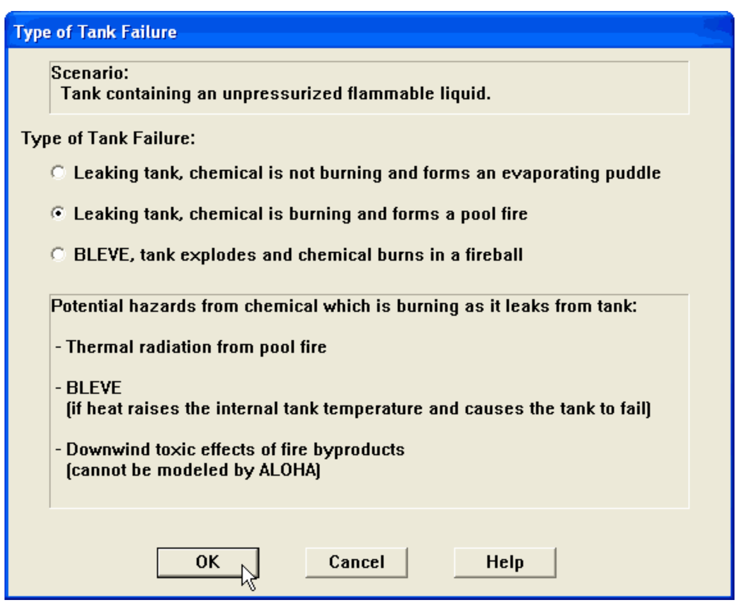
Text Summary

```
SOURCE STRENGTH:
  Leak from hole in vertical cylindrical tank
  Flammable chemical escaping from tank (not burning)
  Tank Diameter: 4 feet                   Tank Length: 5.32 feet
  Tank Volume: 500 gallons
  Tank contains liquid                    Internal Temperature: 80° F
  Chemical Mass in Tank: 1.82 tons        Tank is 100% full
  Circular Opening Diameter: 6 inches
  Opening is 10 inches from tank bottom
  Ground Type: Concrete
  Ground Temperature: equal to ambient
  Max Puddle Diameter: Unknown
  Release Duration: 46 minutes
  Max Average Sustained Release Rate: 77.2 pounds/min
     (averaged over a minute or more)
  Total Amount Released: 3,082 pounds
  Note: The chemical escaped as a liquid and formed an evaporating puddle.
  The puddle spread to a diameter of 21.7 yards.

THREAT ZONE:
  Model Run: Heavy Gas
  Red   : 82 yards --- (1000 ppm = ERPG-3)
  Orange: 281 yards --- (150 ppm = ERPG-2)
  Yellow: 564 yards --- (50 ppm = ERPG-1)
```

Modeling a second scenario: pool fire

Now that ALOHA has displayed the downwind distance to the ERPG-2 level, you want to assess the thermal radiation threat if the puddle is ignited by a lightning strike (or other ignition source) and forms a pool fire. For this example, you want to assess the threat assuming that the pool fire occurs soon after the puddle forms. Therefore, you do not need to enter new information for time, atmospheric conditions, or puddle size.

1. When you run multiple scenarios for the same incident, the plots and Text Summary screen from the first scenario will change when you enter new information. Before you start running an additional scenario, either **print** out the threat zone plot and the Text Summary screen or paste them into a word processing document. You'll need the original information to compare the scenarios later.
2. **Close** the threat zone plot window.
3. When you set the source for the first scenario, you told ALOHA that the benzene was leaking from a tank, but it was not burning. You need to return to the Type of Tank Failure screen and tell ALOHA that now the chemical is burning and it has formed a pool fire. Begin by selecting the Tank source again. In the **SetUp** menu, point to **Source**, then select **Tank**. A Tank Size and Orientation dialog box appears.
4. Notice that all of your original information is already entered into the dialog box. The dimensions of the tank have not changed, so you can just click **OK** to move to the next screen.
5. Your original information is still correct on the Chemical State and Temperature and the Liquid Mass or Volume dialog boxes. Click **OK** on each screen until the Type of Tank Failure dialog box appears.
6. Choose the **Leaking tank, chemical is burning and forms a pool fire** option. Click **OK**. An Area and Type of Leak dialog box appears.



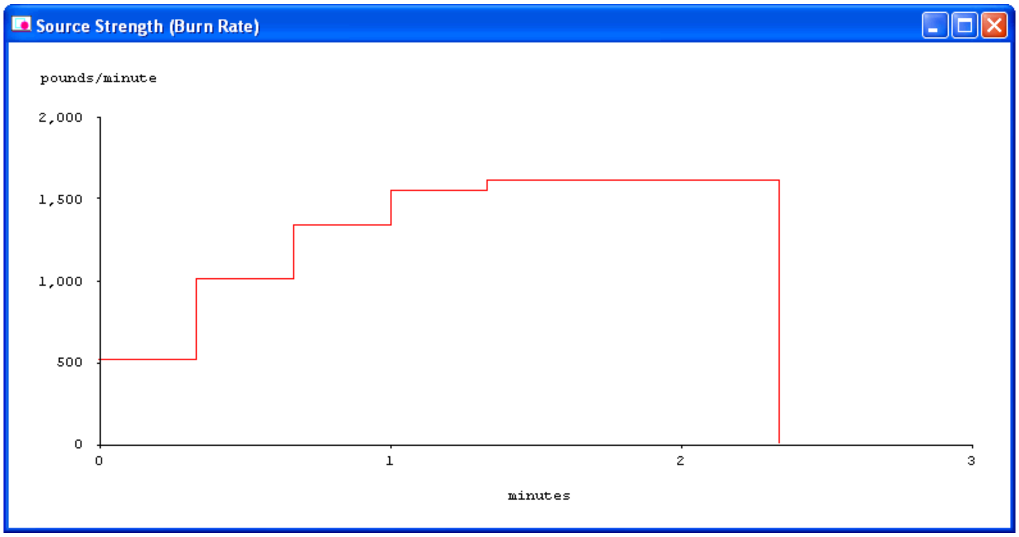
7. Your original information is still correct on the Area and Type of Leak, Height of the Tank Opening, and Maximum Puddle Size dialog boxes. Click **OK** on each screen.

The source strength information that you have entered, and the results of ALOHA's source strength calculations, appear in the Text Summary. ALOHA estimates that the puddle burns for about two minutes, and that the Maximum Burn Rate is 1,610 pounds per minute. Notice that ALOHA estimates that the puddle reached a maximum diameter of 15.0 yards, which is smaller than the 21.7 yards estimated for the evaporating puddle because the chemical is being consumed in the fire before the puddle can spread to the larger diameter.

Text Summary

```
SITE DATA:
  Location: BATON ROUGE, LOUISIANA
  Building Air Exchanges Per Hour: 0.58 (unsheltered single storied)
  Time: August 20, 2006  2230 hours CDT (user specified)

CHEMICAL DATA:
  Chemical Name: BENZENE                  Molecular Weight: 78.11 g/mol
  ERPG-1: 50 ppm      ERPG-2: 150 ppm     ERPG-3: 1000 ppm
  IDLH: 500 ppm       LEL: 12000 ppm      UEL: 80000 ppm
  Carcinogenic risk - see CAMEO
  Ambient Boiling Point: 176.1° F
  Vapor Pressure at Ambient Temperature: 0.13 atm
  Ambient Saturation Concentration: 134,835 ppm or 13.5%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 7 miles/hour from SW at 10 meters
  Ground Roughness: open country          Cloud Cover: 7 tenths
  Air Temperature: 80° F                  Stability Class: D
  No Inversion Height                     Relative Humidity: 75%

SOURCE STRENGTH:
  Leak from hole in vertical cylindrical tank
  Flammable chemical is burning as it escapes from tank
  Tank Diameter: 4 feet                   Tank Length: 5.32 feet
  Tank Volume: 500 gallons
  Tank contains liquid                    Internal Temperature: 80° F
  Chemical Mass in Tank: 1.82 tons        Tank is 100% full
  Circular Opening Diameter: 6 inches
  Opening is 10 inches from tank bottom
  Max Puddle Diameter: Unknown
  Max Flame Length: 26 yards              Burn Duration: 2 minutes
  Max Burn Rate: 1,610 pounds/min
  Total Amount Burned: 3,082 pounds
  Note: The chemical escaped as a liquid and formed a burning puddle.
  The puddle spread to a diameter of 15.0 yards.
```

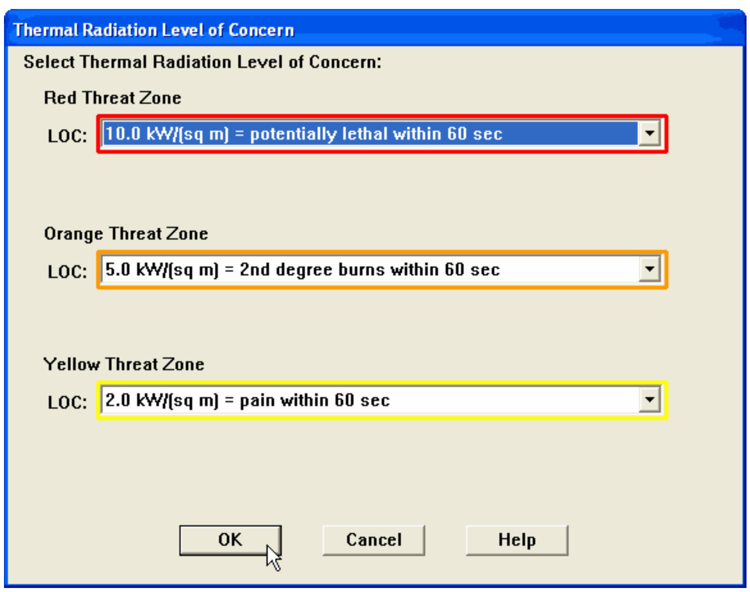
8. Choose **Source Strength** from the **Display** menu to see the source strength graph for this scenario. The graph shows the predicted averaged burn rate.



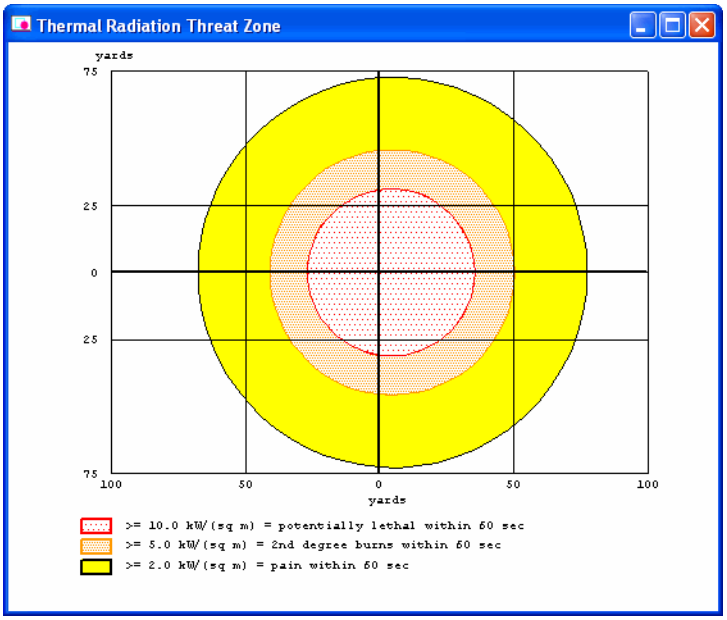
ALOHA estimates that the pool fire would last just under 2 and a half minutes. (In the Text Summary, ALOHA listed the burn duration as 2 minutes. ALOHA rounds duration estimates to the nearest whole minute on the Text Summary screen, but uses the more precise source strength value in its threat calculations.) The increase in burn rate for the first minute and a half is due to the growing puddle size as the chemical continues to leak from the tank.

Choosing LOCs and creating a threat zone plot for the pool fire

1. Choose **Threat Zone** from the **Display** menu. A Thermal Radiation Level of Concern dialog box appears.
2. You want to know the thermal radiation threat for the pool fire. Keep ALOHA's default LOCs and click **OK**. ALOHA will display a threat zone plot for this release.



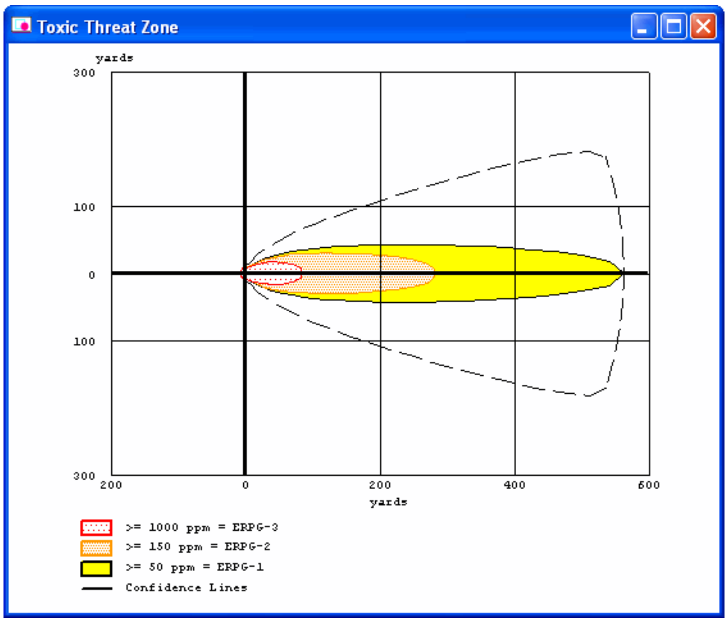
You'll see ALOHA's threat zone plot for this scenario, showing three nearly circular thermal radiation threat zones. The red threat zone represents the worst hazard level, and the orange and yellow threat zones represent areas of decreasing hazard. Unlike the toxic threat, the thermal radiation threat extends in all directions simultaneously. But it extends a little farther in the downwind direction. For example, ALOHA estimates that the orange threat zone will extend 51 yards in the downwind direction. This threat distance is shown in the Text Summary. The orange threat zone extends only about 40 yards in the upwind direction. This difference exists because the wind tilts the flames in the downwind direction—leading to a greater thermal radiation threat in that direction. It is important to realize that there may be additional hazards that are not modeled by ALOHA, including secondary fires and explosions.

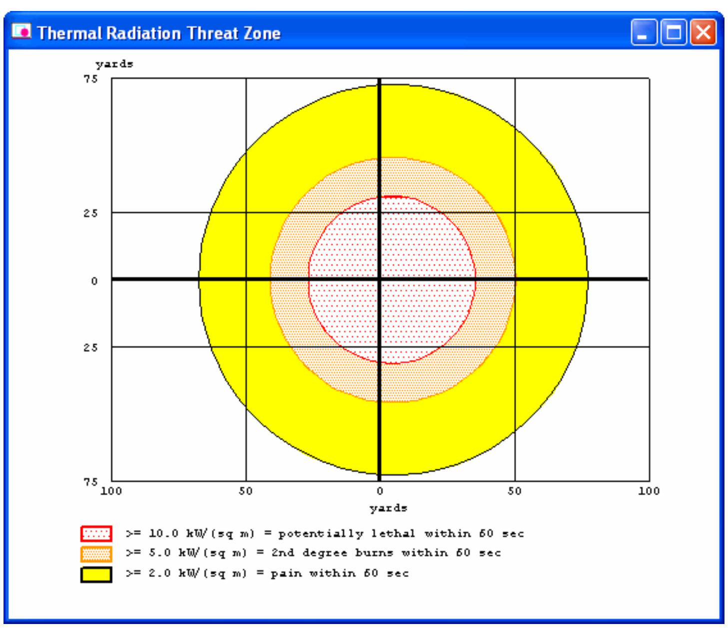


Check the Text Summary for this release.

```
Text Summary

SOURCE STRENGTH:
  Leak from hole in vertical cylindrical tank
  Flammable chemical is burning as it escapes from tank
  Tank Diameter: 4 feet                    Tank Length: 5.32 feet
  Tank Volume: 500 gallons
  Tank contains liquid                     Internal Temperature: 80° F
  Chemical Mass in Tank: 1.82 tons         Tank is 100% full
  Circular Opening Diameter: 6 inches
  Opening is 10 inches from tank bottom
  Max Puddle Diameter: Unknown
  Max Flame Length: 26 yards               Burn Duration: 2 minutes
  Max Burn Rate: 1,610 pounds/min
  Total Amount Burned: 3,082 pounds
  Note: The chemical escaped as a liquid and formed a burning puddle.
  The puddle spread to a diameter of 15.0 yards.

THREAT ZONE:
  Threat Modeled: Thermal radiation from pool fire
  Red   : 36 yards --- (10.0 kW/(sq m) = potentially lethal within 60 sec)
  Orange: 51 yards --- (5.0 kW/(sq m) = 2nd degree burns within 60 sec)
  Yellow: 78 yards --- (2.0 kW/(sq m) = pain within 60 sec)
```

Compare the threat zone plots and the Text Summary screens from both of the scenarios. (The threat distances from the Text Summary screens are summarized in a table below.) The origin (0,0) on both plots represents the center of the puddle. ALOHA estimates that the red toxic threat zone—the worst hazard level—extends primarily in the downwind direction for about 82 yards. The worst of the thermal radiation threat (the red zone) is predicted to extend roughly 30 yards in all directions—and a little farther in the downwind direction. Notice the role that the direction of the wind plays in both scenarios. The toxic threat is confined primarily to the area downwind of the release, and even though the thermal radiation threat occurs in all directions it too is shifted downwind from the origin.





Scenario	Toxic Dispersion	Pool Fire
Threat Modeled	Toxicity	Thermal radiation
Red Threat Zone	82 yards	36 yards
Orange Threat Zone	281 yards	51 yards
Yellow Threat Zone	564 yards	78 yards

AIR SAMPLE COLLECTION

STUDENT OBJECTIVES

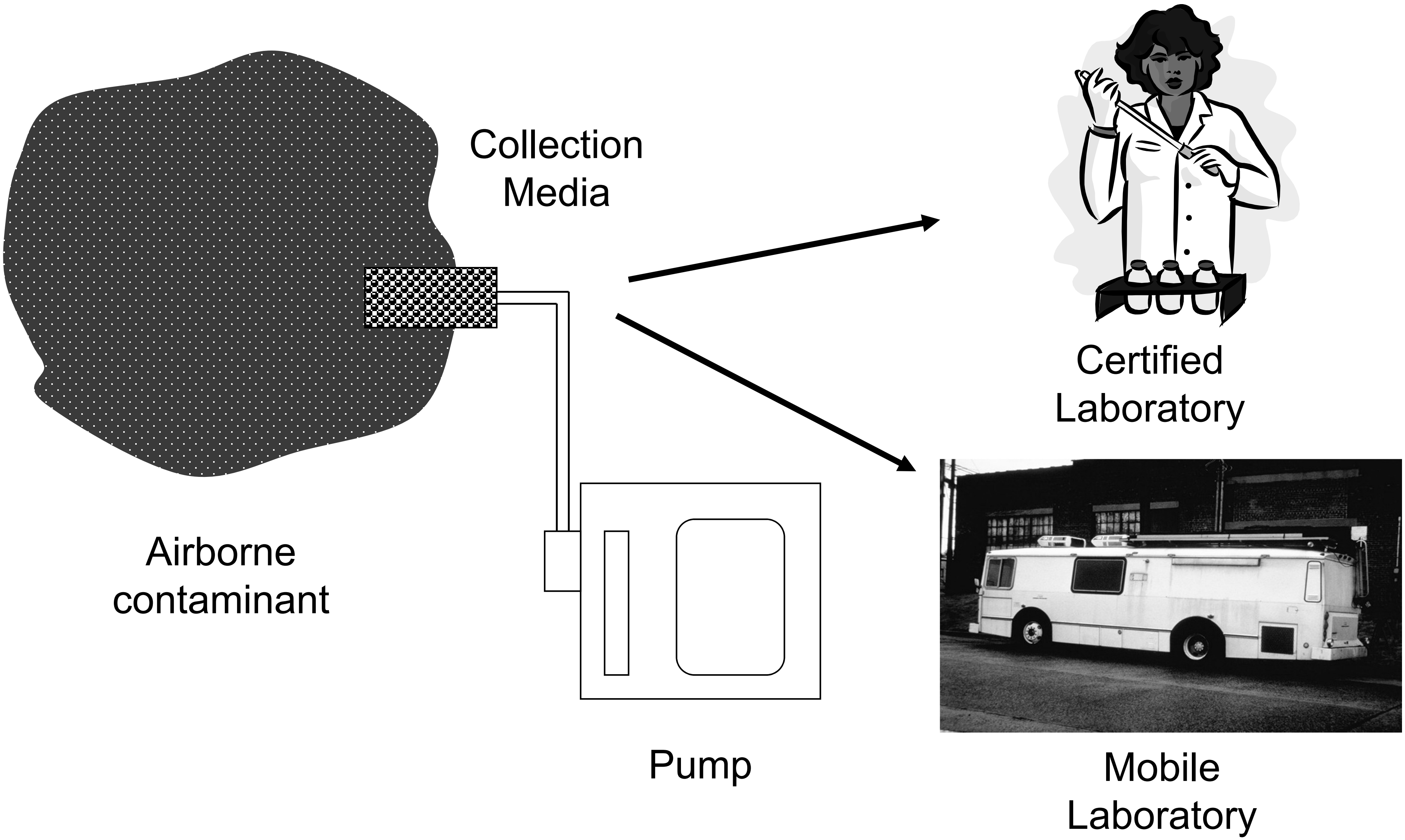
- Define air sample collection
- List four uses of air samples
- List three sources of air sampling methods
- Give an example of a filter, a solid sorbent and a sampling pump
- Compare bag sampling to canister sampling

AIR SAMPLING

Refers to the use of a sampling pump and collection media that produce samples that must be sent to a laboratory for analysis.

SOURCE: US EPA 1993

AIR SAMPING METHODS



AIR SAMPLE COLLECTION USES

- Identify and quantify airborne chemicals
- Evaluate personal exposures
- Evaluate releases from the site
- Obtain data for public health/ecological risk assessments

ASC vs DRI

- Identification
- Accuracy
- Detection limits
- Special methods

AIR SAMPLING METHODS

- What data do you need?
- Can you specify method?
- What does lab want?
- May be more than one method
- Do you need certified or accredited laboratory?

U.S. EPA

- Compendium of Methods for the Determination of :
  - Toxic Organic Compounds in Ambient Air (TO)
  - Inorganic Compounds in Ambient Air (IO)
- Criteria Pollutants
- www.epa.gov/ttn/amtic

NIOSH

Address http://www.cdc.gov/niosh/nmam/

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NIOSH Manual of Analytical Methods (NMAM)

NMAM is a collection of methods for sampling and analysis of contaminants in workplace air, and in the blood and urine of workers who are occupationally exposed. These methods have been developed or adapted by NIOSH or its partners and have been evaluated according to established experimental protocols and performance criteria. NMAM also includes chapters on quality assurance, sampling, portable instrumentation, etc.

Individual analytical methods are in Adobe Acrobat format and require the free Acrobat Reader.

Links to NMAM Methods by Chemical Name or Method Number:

Chemical: A | B | C | D | E | F | G | H | I | K | L | M | N | O | P | R | S | T | V | W | X | Y | Z

Chemical CAS Number: 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9, ALL

NIOSH Method: 0 - 2000 | 2001 - 4000 | 4001 - 6000 | 6001 - 8000 | 8001 - 9999

Chapters
The NMAM Chapters contain useful information on methods, Quality Assurance, method evaluation, biological monitoring, aerosols, and special measurement considerations.

Additional Information

Note: The following pages are in Adobe Acrobat format and require the free Acrobat Reader.

- Method Finder
- Appendixes
  - A. Unit Equivalent
  - B. Air Concentration Calculations for Comparison to OSHA Standard
- Glossary of Abbreviations

NMAM
NIOSH Manual of Analytical Methods

NMAM Index

What's New?

Order NMAM

OSHA

Address http://www.osha.gov/dts/sltc/methods/toc.html

U.S. Department of Labor
Occupational Safety & Health Administration

www.osha.gov

Search GO Advanced Search | A-Z Index

<<< Back to Sampling and Analytical Methods

Printing Instructions

Index of Sampling and Analytical Methods

Methods Search
Search

Go to 'KEY' for definitions of abbreviations.

Alphabetic Table of Methods - A

A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z | Key

Substance and Method Number	CAS Number(s)	Instrument / Sampler
Acetaldehyde; 68; *Fully Validated*	75-07-0	GC/NPD; XAD-2 coated with 2-HMP
Acetamide; PV2084; *Partially Validated*	60-35-5	GC/NPD; Silica Gel
Acetic Acid; ID186SG; *Partially Validated*	64-19-7	IC; CSC
Acetic Acid; PV2119; *Partially Validated*	64-19-7	IC; CSC
Acetic Anhydride; 82; *Fully Validated*	108-24-7	GC/NPD; GFF coated with 1-2PP

http://www.dol.gov/

OTHER COLLECTION AND ANALYTICAL METHODS

- American Society for Testing and Materials (ASTM)
- International Organization of Standards (ISO)
- Specialty methods

EXAMPLES

- Asbestos
  - U.S. EPA: none, use other sources
  - NIOSH: 7400, 7402 (both filter)
  - OSHA: ID-160 (filter)
- Benzene
  - U.S. EPA: TO-17 (sorbent), TO-14 (canister)
  - NIOSH: 1500, 1501, 2549, 3700, 3800
  - OSHA: 12 (sorbent); 1005 (sorbent – active or passive)
- PCBs
  - U.S. EPA: TO-10A (polyurethane foam)
  - NIOSH: 5503 (filter + sorbent)
  - OSHA: PV2089 (filter + sorbent)

STANDARD OPERATING PROCEDURES (SOPs)

- Expand upon a method by modifying or adding steps
- Field procedures
- For example:
  - NIOSH Method 7400 specifies the type of filter to use, but only that a pump with a specified flow rate be use.
  - An SOP may require Method 7400 rather than 7402, and describe how to calibrate the sampling pump

STANDARD OPERATING PROCEDURES

STANDARD OPERATING PROCEDURES

ACTIVITY-BASED AIR SAMPLING FOR ASBESTOS

CONTENTS

ACTIVITY-BASED AIR SAMPLING FOR ASBESTOS

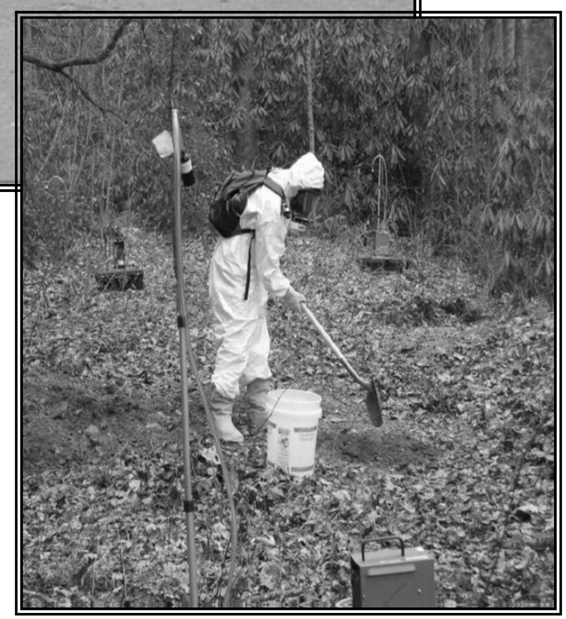
- "1% definition of asbestos should not be used and that a risk-based, site-specific action level should be used when evaluating the need for removal or remedial actions."*
- Soil concentrations/dust concentrations not adequate measure of what is inhaled
- Extrapolations not available
- Air concentration is best measure

*OSWER Directive 9345.4-05

ERT SOP 2084

- Uses personal and area samplers
- Media and pumps same as found in NIOSH method 7400 and ERT SOP 2015
- Pumps worn while field personnel simulate activities that potential exposed populations may do

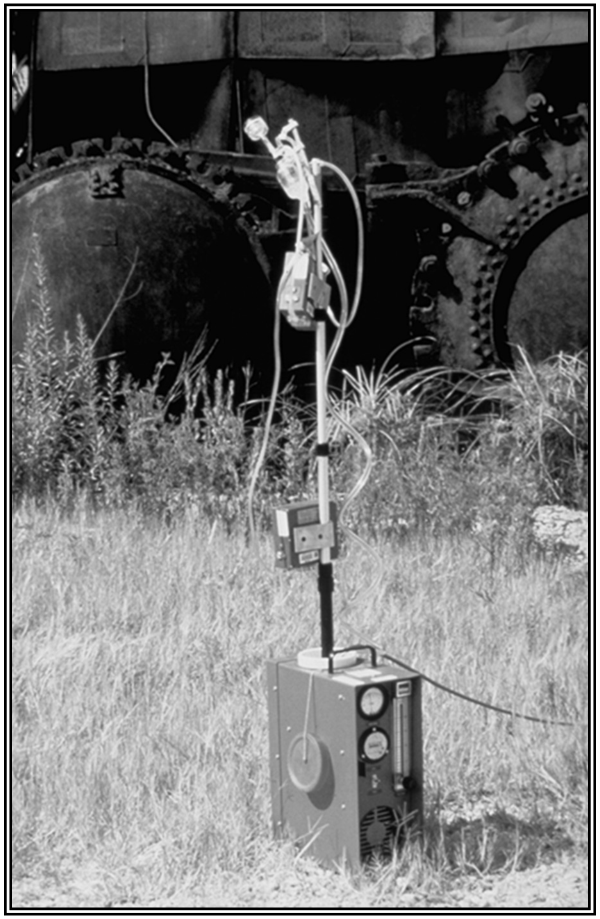
SITE-SPECIFIC ACTIVITIES



Source: OSWER Asbestos Technical Review Workgroup

PERSONAL SAMPLER

AREA SAMPLER



COLLECTION MEDIA
Types of Contaminants

- Aerosols/particulates (nonvolatile)
- Gases and vapors (volatile)
- Combination (semivolatile)

FILTER MEDIA
Examples

FILTER MEDIA	APPLICATIONS
• Mixed cellulose ester (MCE)	• Metals; asbestos
• Glass fiber	• Pesticides
• Polyvinyl chloride	• Total particulates; hexavalent chromium
• Teflon	• Alkaline dusts

FILTERS AND HOLDERS

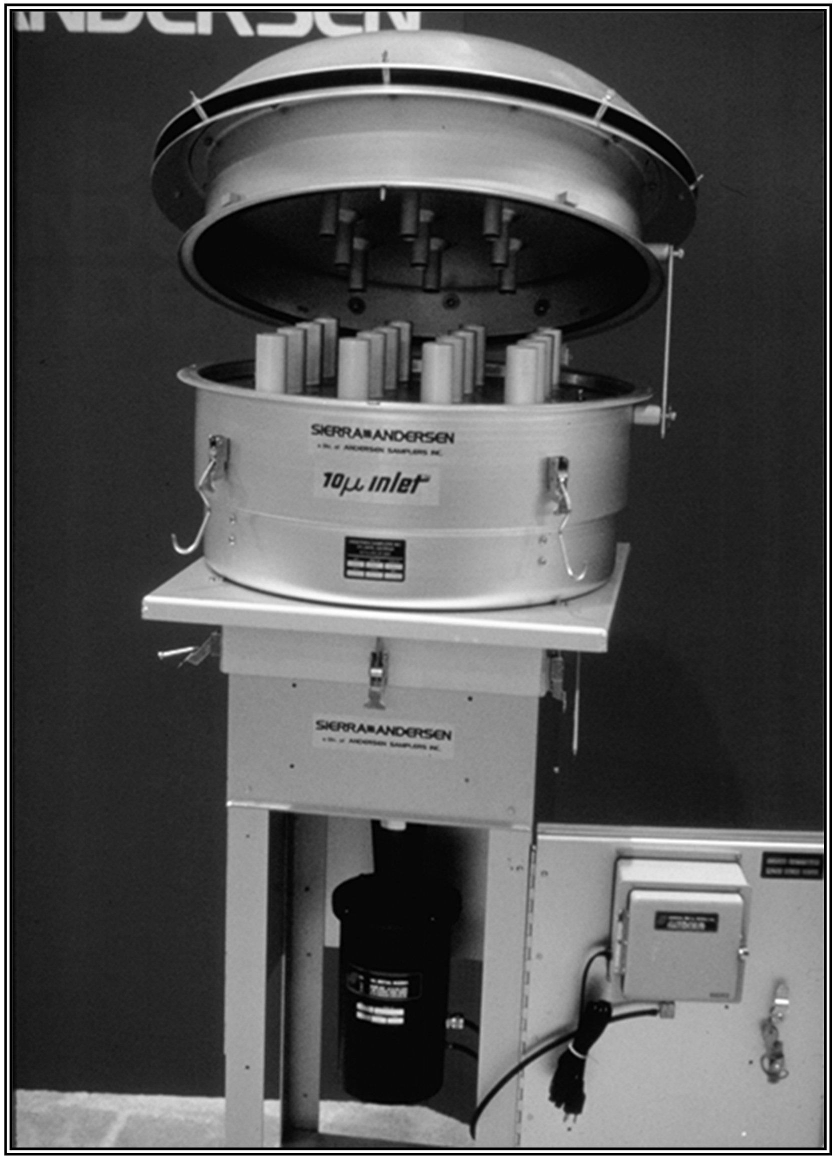
SPECIAL HOLDERS

AEROSOLS/PARTICULATES Size Selection Terminology

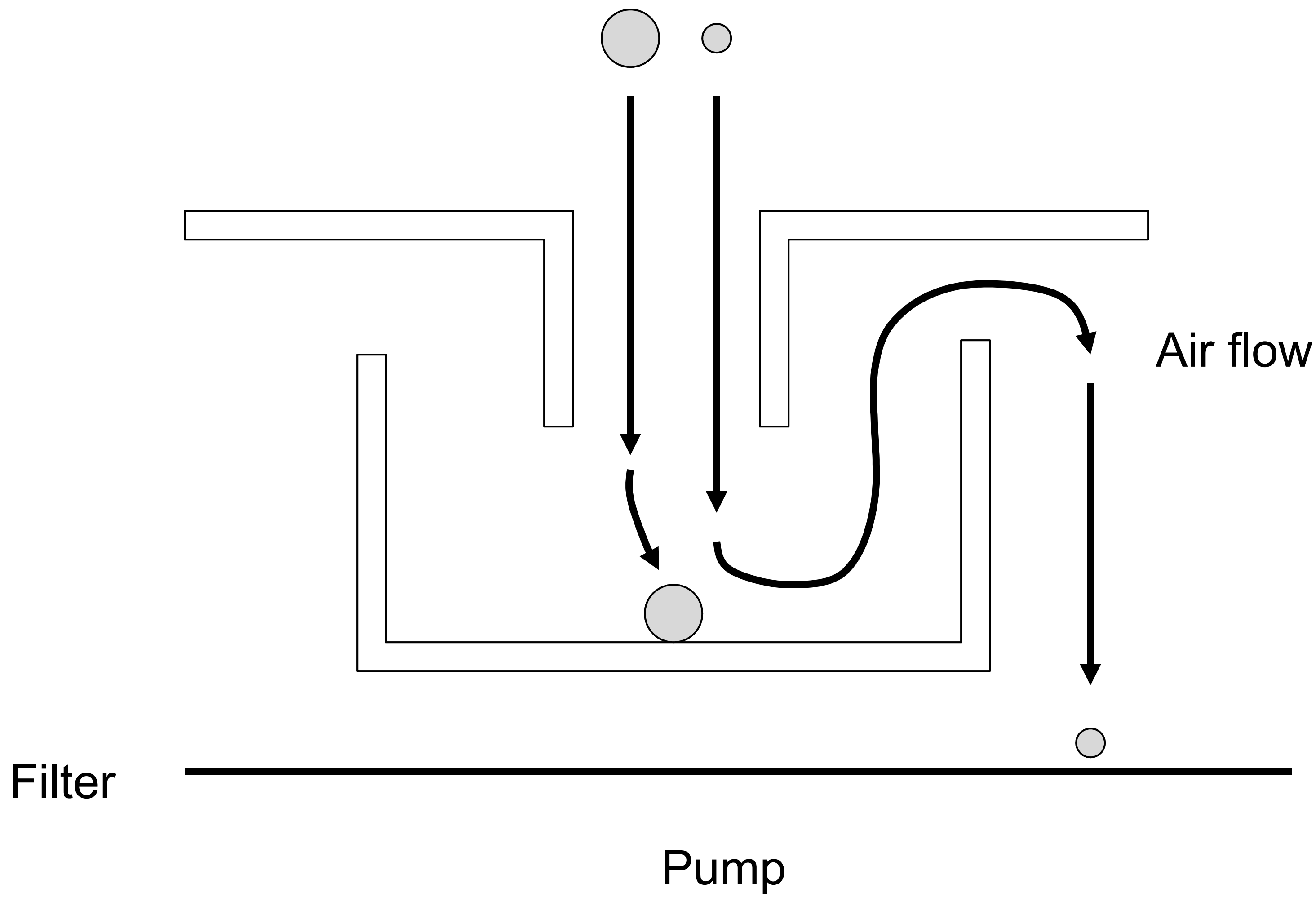
Environmental

- Total suspended particulate (TSP)
- Particulate matter – 10 micron (PM_{10})
- Particulate matter – 2.5 micron ($PM_{2.5}$)

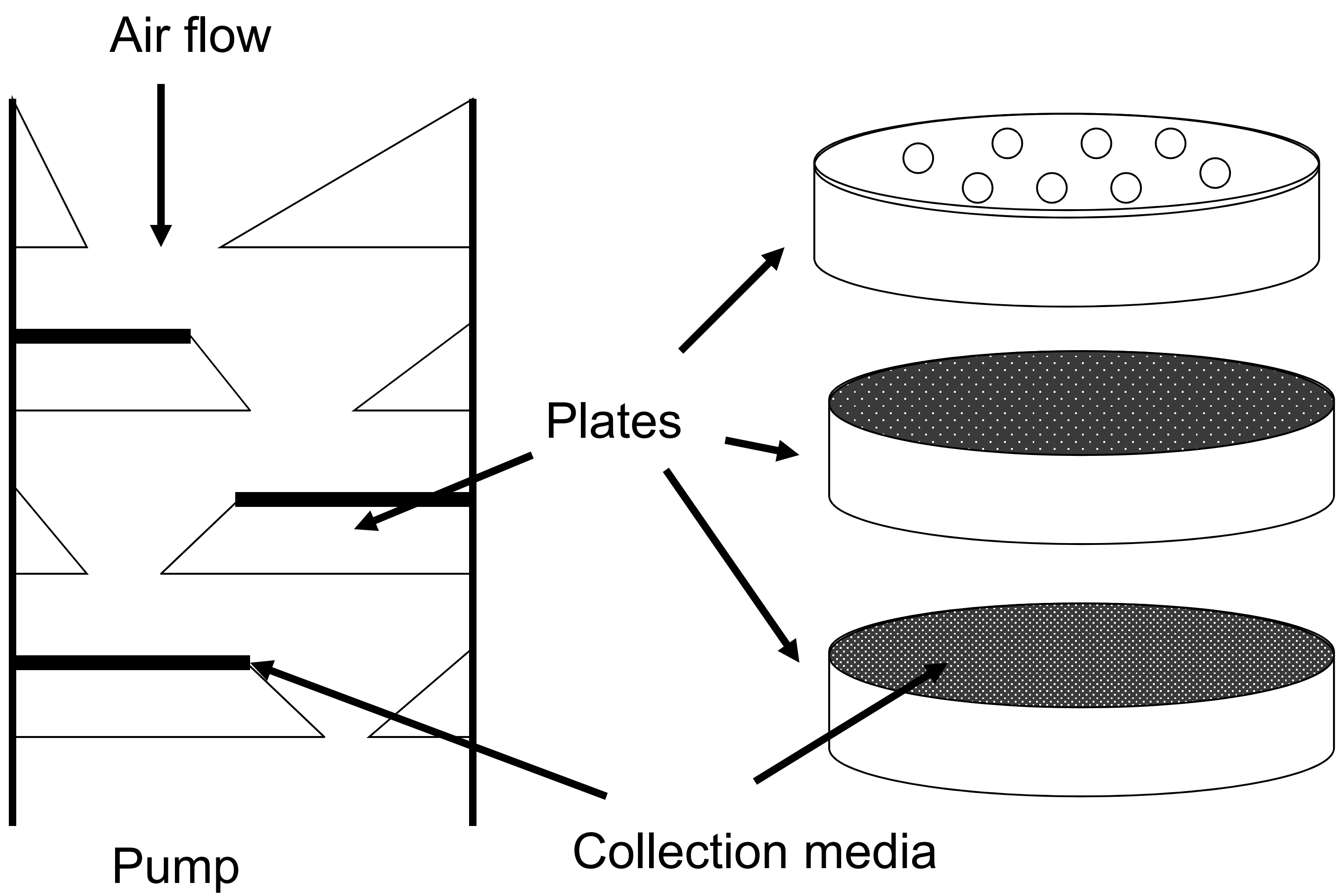
PM10 SAMPLER



AEROSOL SIZE SELECTION
Inertial Impactor



AEROSOL SIZE SELECTION
Cascade Impactor

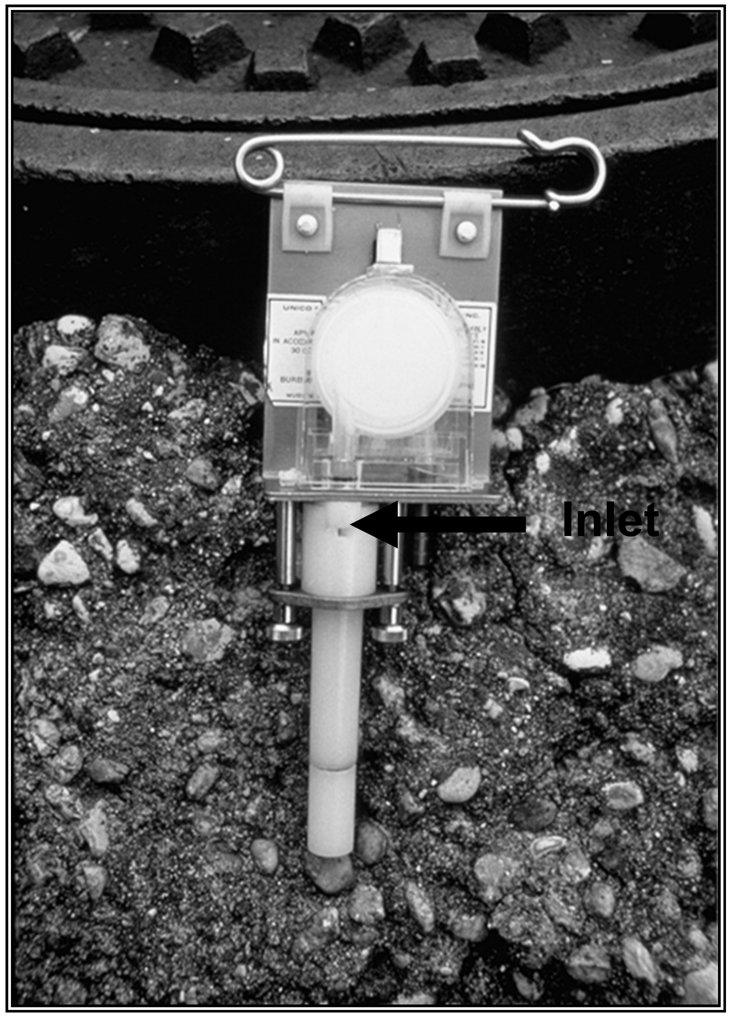


AEROSOLS/PARTICULATES
Size Selection Terminology

Occupational

- Total
- Inhalable
- Thoracic
- Respirable

PERSONAL CYCLONE



GASES AND VAPORS
Examples

- Organic vapors
  - Benzene
  - Trichloroethene
  - Ethanol
- Inorganic gases
  - Ammonia
  - Hydrogen chloride
  - Hydrogen cyanide

GASE AND VAPORS Collection Methods

- Solid sorbents
- Liquid sorbents
- Whole air collection

SOLID SORBENT TUBES

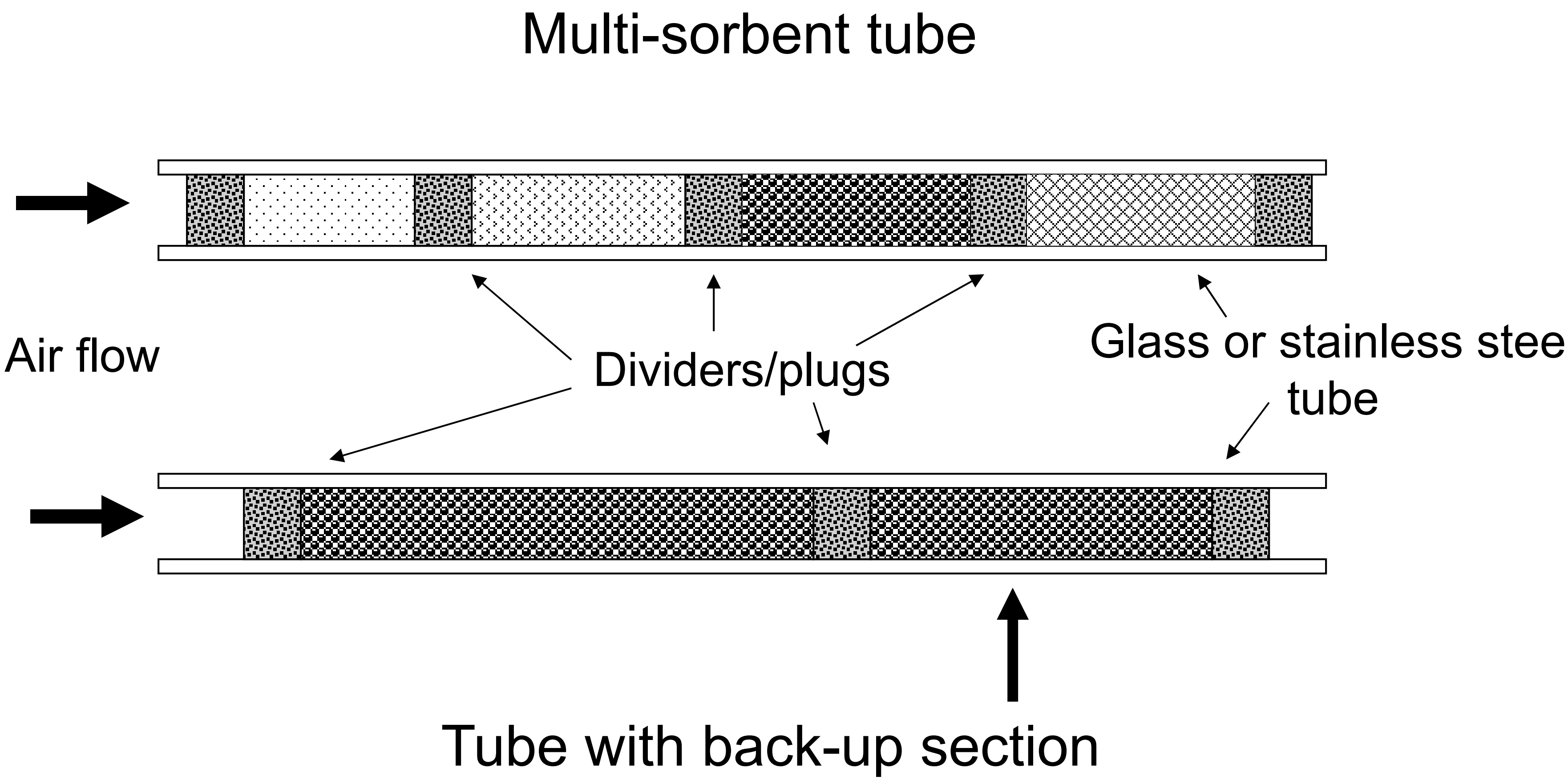
SOLID SORBENT MEDIA
Examples

SOLID SORBENT	APPLICATIONS
• Activated carbon	• Nonpolar organics (NIOSH)
• Tenax®	• Volatile, nonpolar organics (EPA)
• Silica gel	• Polar organics (NIOSH)
• Gold-coated glass beads	• Mercury vapor (EPA)

SOLID SORBENTS CONSIDERATIONS

- Selection of sorbent – no universal medium
- Sorption efficiency – will it collect enough of chemical for analysis?
- Breakthrough – will sample be lost?
- Stability/special handling

SORBENT TUBE



BREAKTHROUGH FACTORS

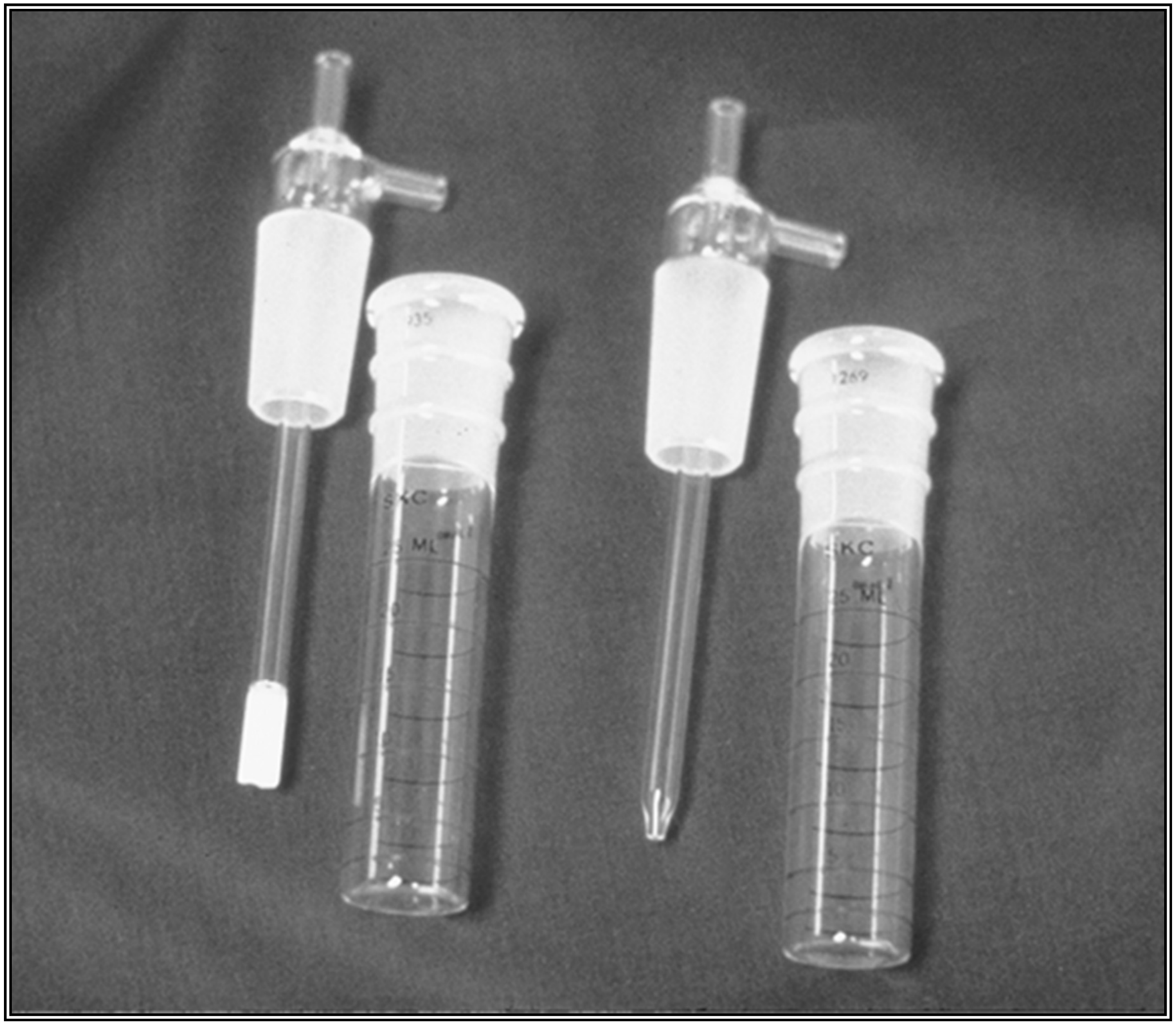
- Sample volume
- Chemical concentration
- Other chemicals present
- Temperature
- Humidity

SPECIAL HANDLING

LIQUID MEDIA
Examples

MEDIA	APPLICATIONS
• 0.1 N NaOH	• Cresol/Phenol (EPA)
• Aniline	• Phosgene (EPA)
• DNPH reagent	• Aldehydes/ketones (EPA)
• 0.1 M HCl	• Hydrazine (NIOSH)

IMPINGERS/BUBBLERS



IMPINGER/BUBBLER

LIQUID SORBENT CONSIDERATIONS

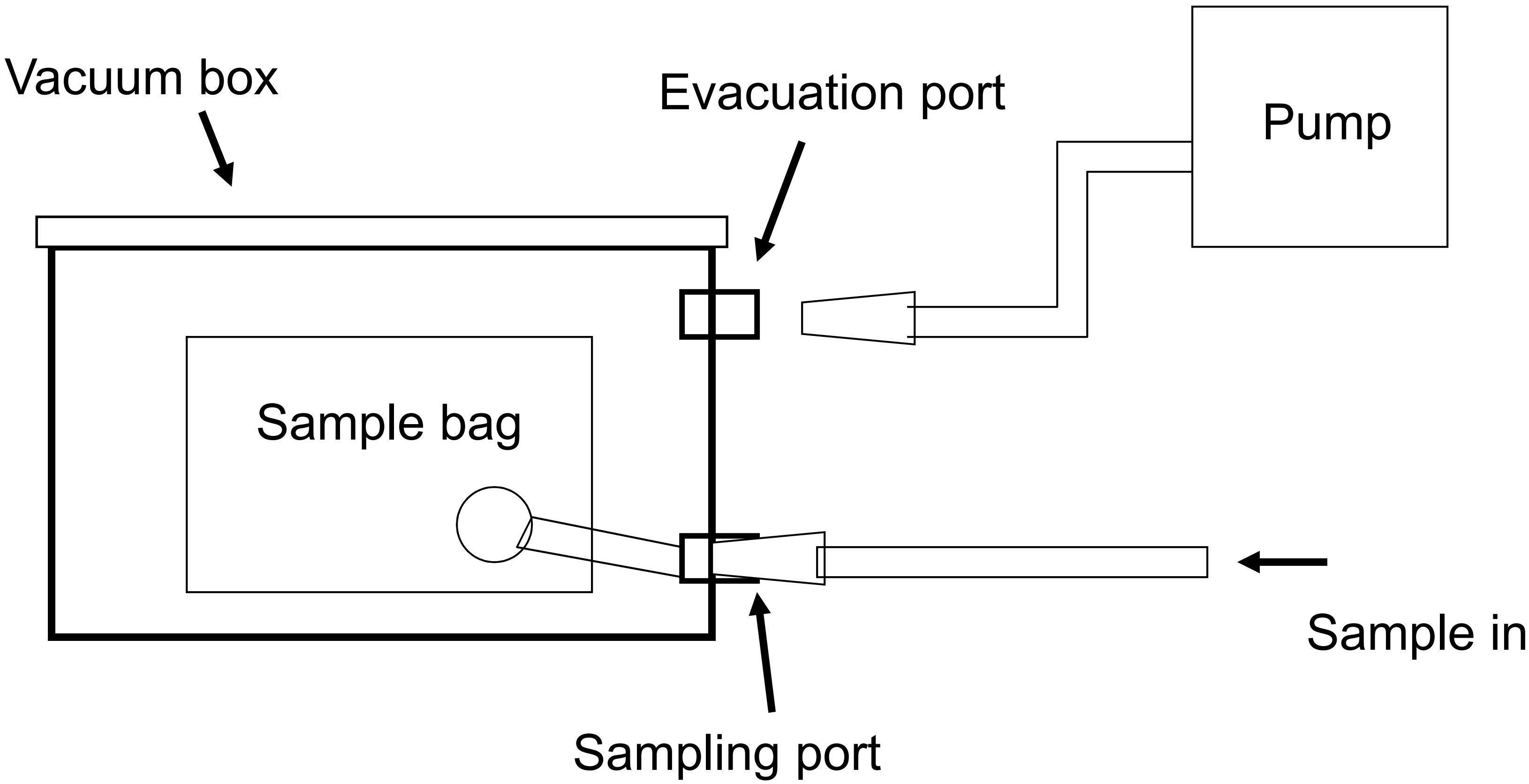
- Spillage
- Fragile containers
- Hazardous liquids may be used
- Stability
- Evaporation

WHOLE AIR COLLECTION

BAG FILLING

Warning: Sample cross contamination possible

VACUUM BOX
"Sampling Lung"



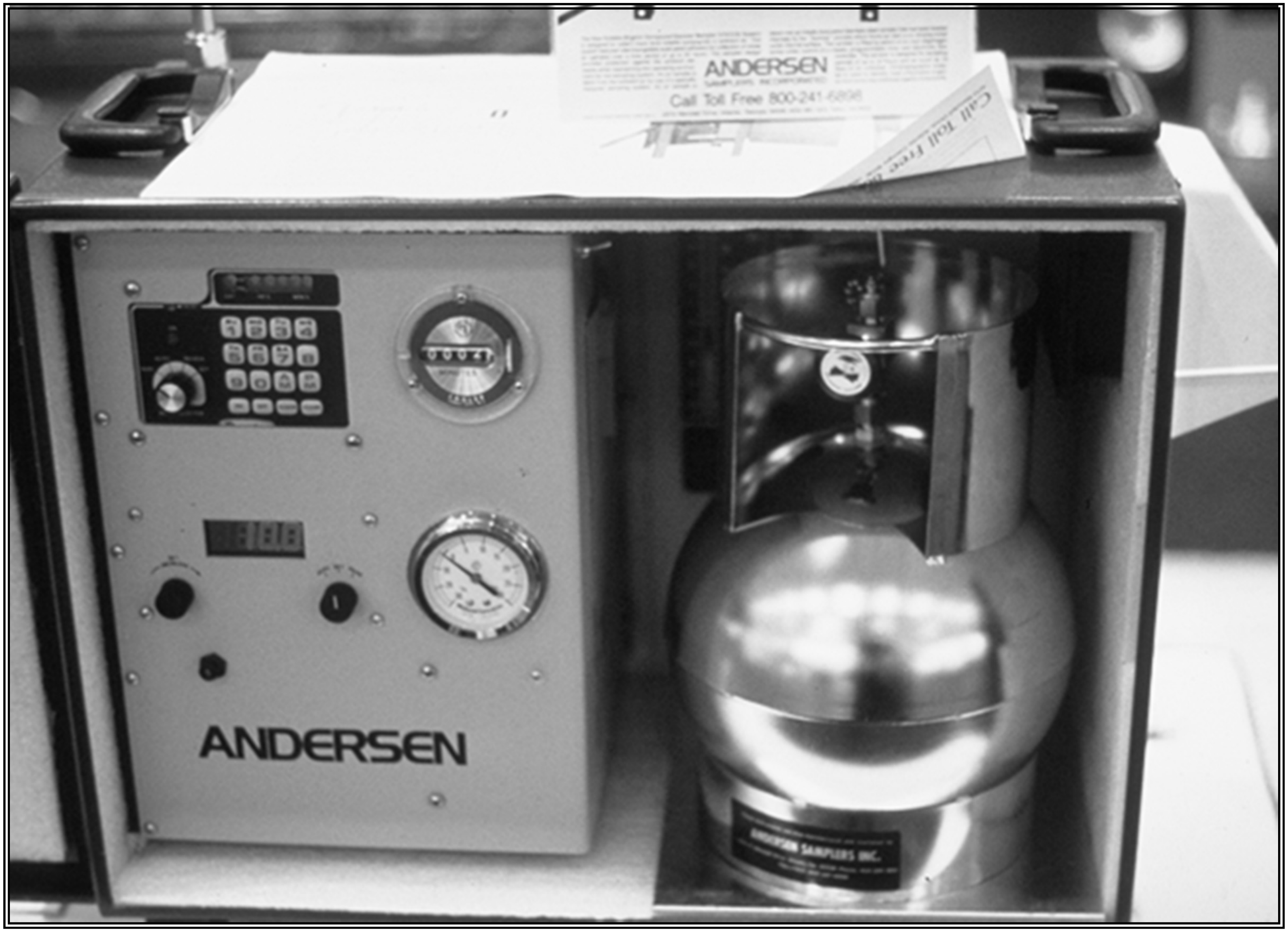
SOURCE: U.S. EPA 1991

VACUUM BOX


SAMPLER
0001
SAMPLE PERIOD–MINUTES
MODE
SET-UP
START
HOLD
723659

CANISTER

CANISTER



BAG vs CANISTER

BAG	CANISTER
• Short sample time	• Long sample time
• Need field pump	• Need lab pump
• Less stable sample	• More stable sample
• Disposable – don’t clean	• Reusable – need to clean
• Cannot pressurize	• Can pressurize
• Inexpensive	• Expensive

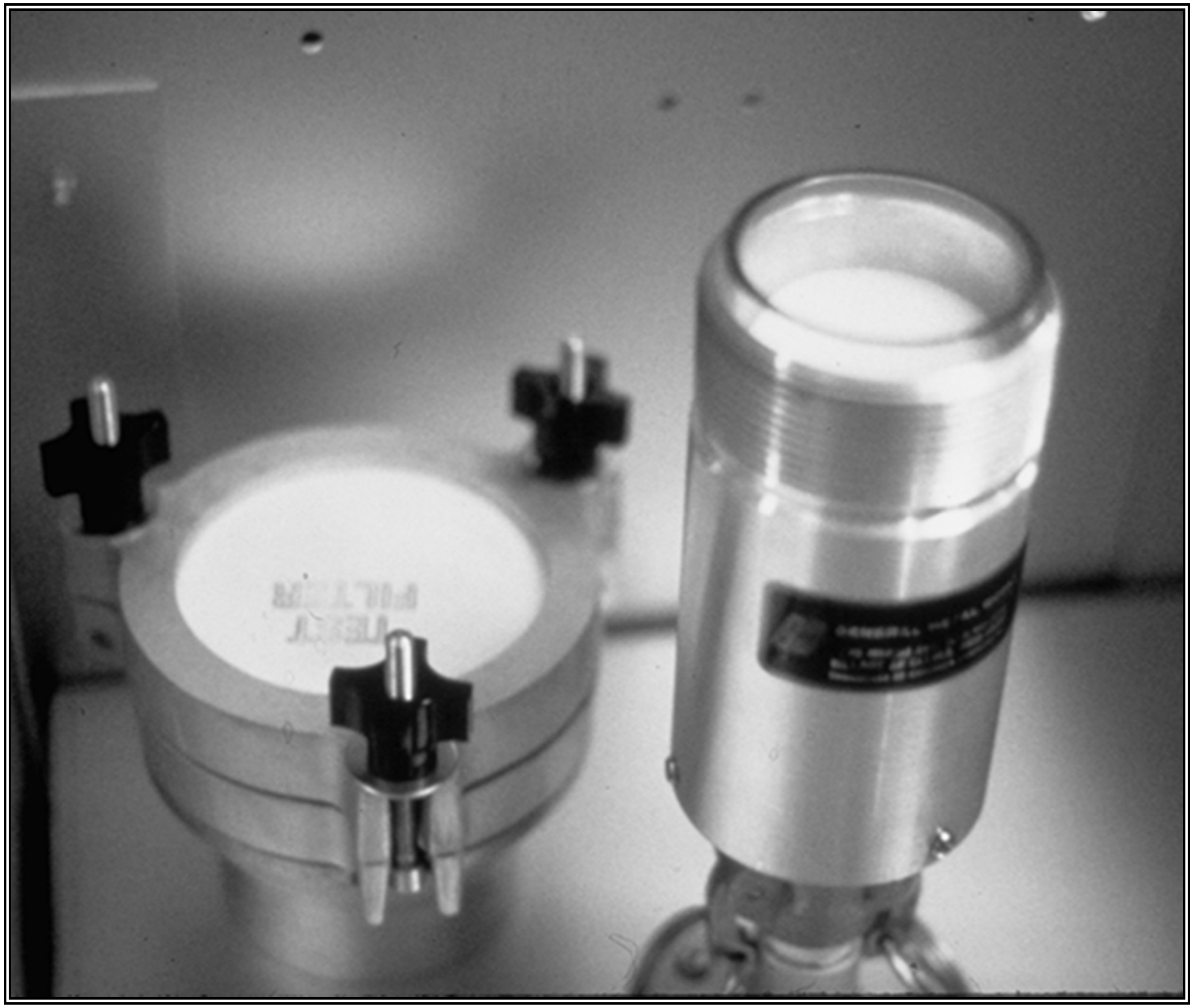
COMBINATION MEDIA

- Some chemicals have such a low vapor pressure that very little would be a vapor and most would be attached to particulates, like soil.
- But, because of their toxicity, you want to collect both the vapor and solid phase.
- If only the particulate were collected, the flow of air across the filter may also "air strip" the contaminant.
- So media to collect the solid and vapor phases is used.

COMBINATION MEDIA
Examples

MEDIA	APPLICATIONS
• Quartz filter + polyurethane foam	• PCBs/pesticides (EPA); PAHs (EPA)
• Glass filter + Florisil	• PCBs (NIOSH)
• PVC membrane + 0.1 N KOH	• Cyanides (NIOSH)
• OVS-2 tube (13 mm quartz fiber filter + XAD®-2)	• Pesticides (NIOSH)

COMBINATION SAMPLER

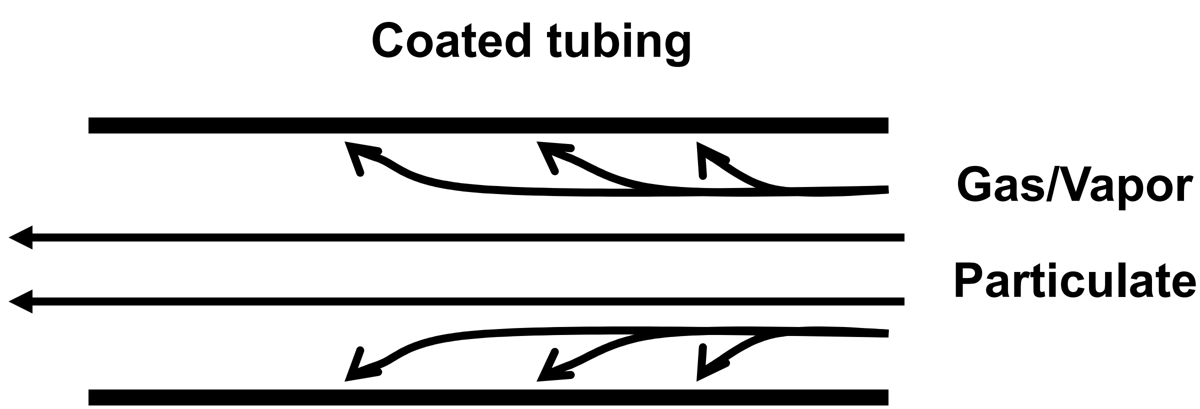


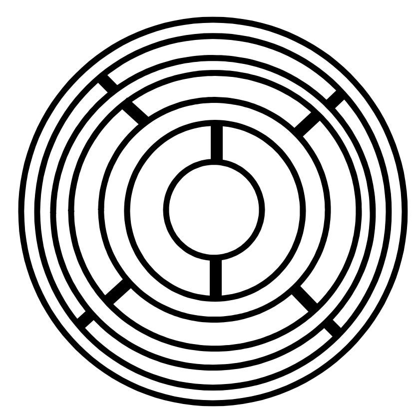
COMBINATION SAMPLER

ANNULAR DENUDER

- Vapor/gas collector precedes particulate collector
- Can determine vapor/gas concentration
- Remove a vapor/gas interference
- Example: EPA IO-4.1 and 4.2

ANNULAR DENUDER



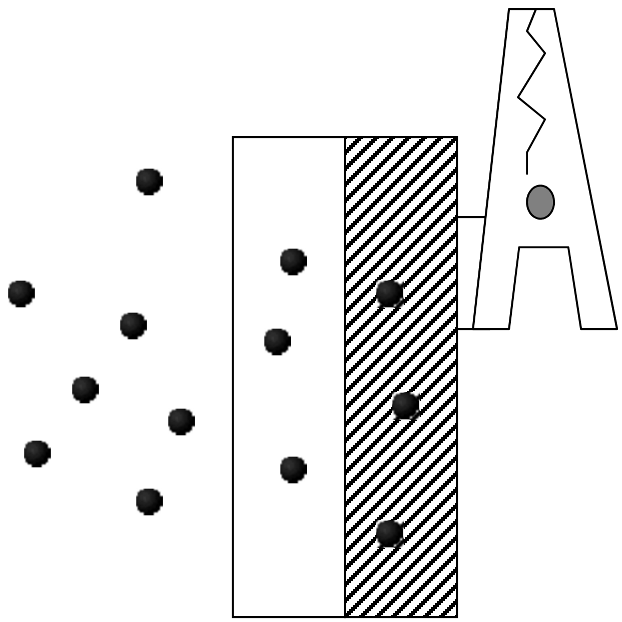


Cross-Sectional View

SAMPLING PUMPS

- Most collection methods require a pump to pull air through the medium
- Different pumps needed for different applications
- Exceptions
  - Evacuated canister
  - Passive samplers (dosimeters)

PASSIVE (DIFFUSIVE) SAMPLER



Chemical diffuses into sampler
and collects on sorbent.

PASSIVE SAMPLERS CONSIDERATIONS

- No pump
- Same analysis as similar sorbents
- Similar limitations
- Early and late exposure bias
- Gas and vapors only

SAMPLING PUMPS
High Vol(ume)

- 2 to 1130 liters per minute (40 cubic feet per minute)
- Normally for ambient air sampling
- Need large pump and power supply

HIGH VOL SAMPLER

SAMPLING PUMPS
High Flow

- 1 to 6 liters per minute
- Normally for personal sampling but can be used for area sampling
- Normally for aerosol sampling, but may be used for short-term vapor sampling

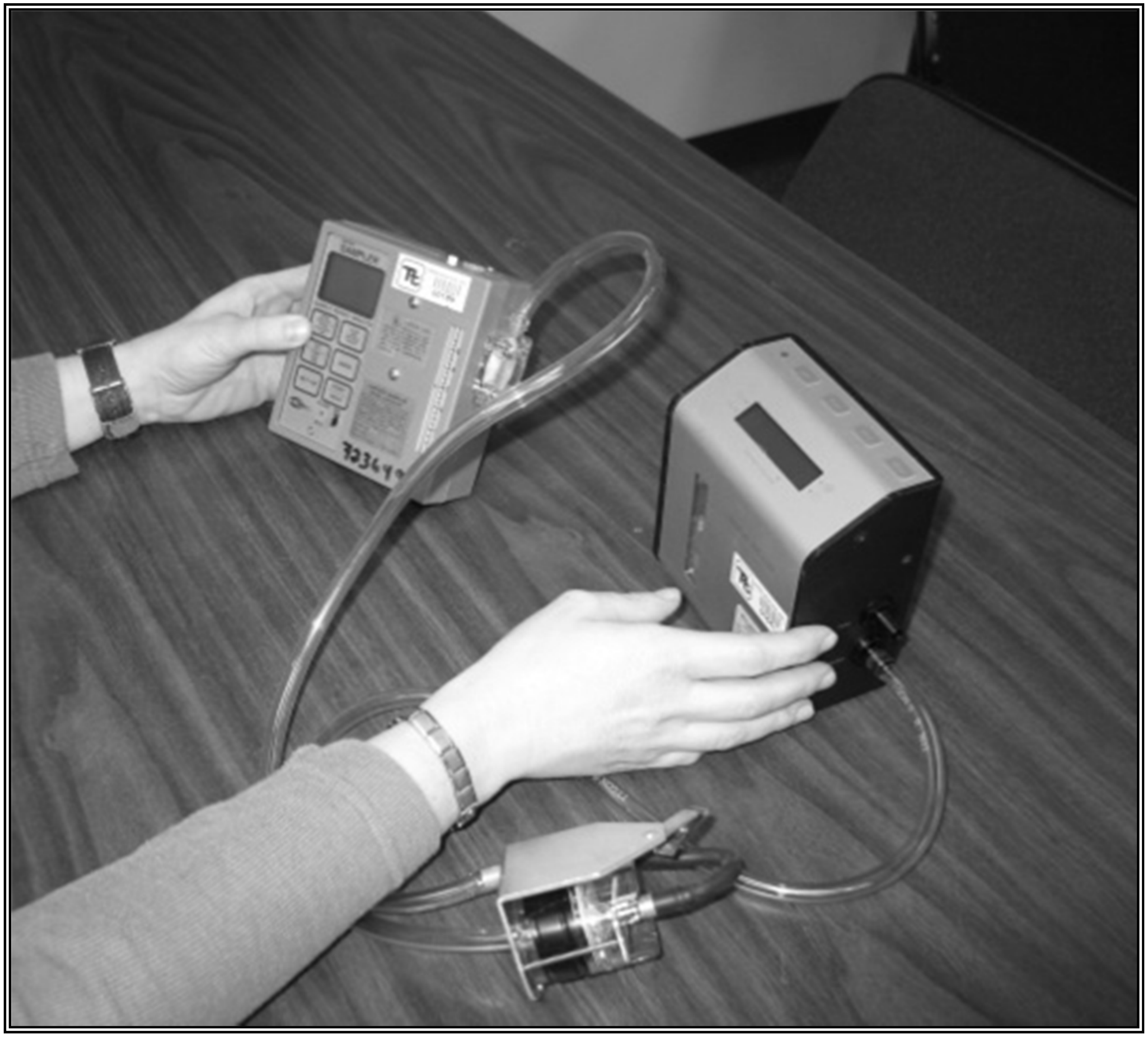
HIGH FLOW PUMP

SAMPLING PUMPS
Low Flow

- 10 to 750 milliliters (cubic centimeters) per minute
- Normally for personal sampling but can be used for ambient air sampling
- Gas and vapor sampling

LOW FLOW PUMP

CALIBRATION



SUMMARY

- Is air sampling needed?
- What method appropriate?
- What can laboratory do?
- Follow method
- Data quality and interpretation

QUESTIONS?

ACRONYMS AND ABBREVIATIONS

ACRONYMS AND ABBREVIATIONS

AAL	air action level
ABIH	American Board of Industrial Hygiene
ACGIH	American Conference of Governmental Industrial Hygienists
AEGL	acute exposure guideline level
AID	argon ionization detector
AIHA	American Industrial Hygiene Association
ALOHA™	areal locations of hazardous atmospheres
ANSI	American National Standards Institute
APA	air pathway assessment; air pathway analysis
ASPECT	Airborne Spectral Photometric Environmental Collection Technology
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
BEI™	biological exposure indices
C	ceiling (as in TLV-C); concentration (in equations)
Ca	carcinogen
CAM	chemical agent monitor
cc/min	cubic centimeters per minute
CDC	Centers for Disease Control
CDS	civil defense set
CEPPO	Chemical Emergency Preparedness and Prevention Office – now part of the Office of Emergency Management
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
cfm	cubic feet per minute
CFR	Code of Federal Regulations
CGI	combustible gas indicator
CH4	methane
CK	cyanogen chloride
Cl	chlorine
CMS	chip measurement system
CO	carbon monoxide
CO_2	carbon dioxide
COMB	combustible
CWA	chemical warfare agent
DHHS	U.S. Department of Health and Human Services

DNPH	2,4-dinitrophenylhydrazine
DQO	data quality objective
DRI	direct-reading instrument
E_m	equivalent exposure for a mixture
e^-	electron
ECBC	Edgewood Chemical Biological Center
ECD	electron capture detector
EMI	electromagnetic interference
EPA	U.S. Environmental Protection Agency
ERPG	Emergency Response Planning Guide (AIHA)
ERT	Environmental Response Team
ERTC	Environmental Response Team Center
ERTP	Environmental Response Training Program
ETV	Environmental Technology Verification
eV	electron volt
FID	flame ionization detector
FM	Factory Mutual Research Corporation
FPD	flame photometric detector
FTIR	fourier transform infrared
GA	Tabun
GB	Sarin
GC	gas chromatograph; gas chromatography
GD	Soman
GPL	general population limit
H	mustard gas
H_2S	hydrogen sulfide
HAZWOPER	Hazardous Waste Operations and Emergency Response
HD	Distilled mustard
HCl	hydrogen chloride
HCN	hydrogen cyanide
ICS	incident command system
IDLH	immediately dangerous to life or health
IE	ionization energy
IMS	ion mobility spectrometer
IP	ionization potential

IR	infrared
ISEA	International Safety Equipment Association
ISC3	Industrial Source Complex version 3 (air dispersion model)
KOH	potassium hydroxide
LCD	liquid crystal display
LED	light-emitting diode
LEL	lower explosive limit
LFL	lower flammable limit
lpm	liters per minute
MACs	maximum allowable concentrations
MAKs	maximum concentration at the workplace (Federal Republic of Germany)
MCE	mixed cellulose ester
mg/m^3	milligram per cubic meter
ml	milliliter
mm	millimeter
MOS	metal-oxide semiconductor
MS	mass spectrometer
MSA	Mine Safety Appliances, Inc.
MSDS	material safety data sheet
MSHA	Mine Safety and Health Administration
N2O	nitrogen dioxide
NaOH	sodium hydroxide
NEC	National Electrical Code
NFPA	National Fire Protection Association
NIJ	National Institute of Justice
NIOSH	National Institute for Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
NRC	Nuclear Regulatory Commission
NTGS	National Technical Guidance Study
O	oxygen atom
O2 or O_2	oxygen molecule
OEL	occupational exposure limit
OH	hydroxide
OIML	International Organization of Legal Metrology

OJP	Office of Justice Programs (U.S. Department of Justice)
OPPT	Office of Pollution Prevention and Toxics
OSHA	Occupational Safety and Health Administration
OSRTI	Office of Superfund Remediation and Technology Innovation
OSWER	Office of Solid Waste and Emergency Response
OVA	organic vapor analyzer (Foxboro®)
OVM	organic vapor meter
P	phosphorous
PAH	polycyclic (or polynuclear) aromatic hydrocarbon
PAL	point, area, line (air dispersion model)
PASAMR	Personal Air Sampling and Air Monitoring Requirements Under 29 CFR 1910.120
PBK	playback
PCB	polychlorinated biphenyl
PEL	permissible exposure limit
PID	photoionization detector
ppb	parts per billion
PPE	personal protective equipment
ppm	parts per million
ppt	parts per trillion
PUF	polyurethane foam
PVC	polyvinyl chloride
RAM	regional air model
RAPID	Remote Air Pollution Infrared Detector
REL	recommended exposure limit
RFI	radio frequency interference
RH	relative humidity; organic chemical
RMP	risk management program
RSCAAL	Remote Sensing Chemical Agent Alarm
SA	shift average
SARA	Superfund Amendments and Reauthorization Act
SAW	surface acoustic wave
SBCCOM	U.S. Army Soldier and Biological Chemical Command
SCBA	self-contained breathing apparatus
SCRAM	Support Center for Regulatory Air Models
SEI	Safety Equipment Institute
SOP	standard operating procedure

SOSG	Standard Operating Safety Guide
SS	chemical-specific sensor
STEL	short-term exposure limit
TAGA	Trace Atmosphere Gas Analyzer
TCD	thermal conductivity detector
TEEL	Temporary Emergency Exposure Limit
TIC	toxic industrial chemical; tentatively identified compound
TIM	toxic industrial material
TLV™	Threshold Limit Value
TWA	time-weighted average
UEL	upper explosive limit
UFL	upper flammable limit
UL	Underwriters' Laboratory, Inc.
USDOJ	U.S. Department of Justice
UV	ultraviolet light
WEEL	Workplace Environmental Exposure Level
WPL	worker population limit